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FINAL OPERATION, MAINTENANCE, AND MONITORING PLAN
PACIFIC SOUND RESOURCES SUPERFUND SITE
MARINE SEDIMENTS UNIT

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ABBREVIATIONS AND ACRONYMS

AET	apparent effects threshold
baz	biologically active zone
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program (EPA)
CMP	Cleanup Management Plan
COC	Chemical of Concern
Corps	U.S. Army Corps of Engineers
CQAP	Construction Quality Assurance Plan
CRDL	contract-required detection limit
CSL	cleanup screening level
CWA	Clean Water Act
DGPS	Differential Global Positioning System
DMMO	Dredged Material Management Office
DMMP	Dredged Material Management Program
DNR	Department of Natural Resources (Washington State)
DQI	data quality indicator
DQO	data quality objective
Ecology	Department of Ecology (Washington State)
EPA	U.S. Environmental Protection Agency
HPAH	high-molecular-weight PAH
LAET	lowest apparent effects threshold
LPAH	low-molecular-weight PAH
MLLW	mean lower low water
MO	monitoring objective
MQO	measurement quality objective
MSU	Marine Sediments Unit
NAD	North American Datum
NAPL	nonaqueous phase liquid
NOS	National Oceanographic Service
NTU	nephelometric turbidity unit
OC	organic carbon
OCN	organic carbon normalized
O&M	operations and maintenance
OMMP	Operation, Maintenance, and Monitoring Plan
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyl
PCDD/F	polychlorinated dibenzodioxins and dibenzofurans

ABBREVIATIONS AND ACRONYMS (Continued)

PGA	peak ground acceleration
PQL	protection quantification limit
PSEP	Puget Sound Estuary Program
PSR	Pacific Sound Resources
PSRMP	PSR Management Plan
RAs 1–4	Remediation Areas 1 through 4
RA	remediation area
RD	Remedial Design (USEPA 2003b)
RI	Remedial Investigation
ROD	Record of Decision (USEPA 1999)
RPD	relative percent difference
RSD	relative standard deviation
SAP	Sampling and Analysis Plan
SMS	sediment management standards
SQS	sediment quality standard(s)
SVOC	semivolatile organic compound
SVPS	sediment vertical profile system
TEQ	toxicity equivalency quotient
TOC	total organic carbon
TVS	total volatile solids
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
VOC	volatile organic compound
WAC	Washington Administrative Code

1.0 INTRODUCTION

This document presents the Operation, Maintenance, and Monitoring Plan (OMMP) for the Pacific Sound Resources (PSR) Superfund Site Marine Sediments Unit (MSU), located in Seattle, Washington. PSR is a U.S. Environmental Protection Agency (EPA)-lead Superfund site; hence management of the site, including the design and construction of the remedy, is the responsibility of EPA. The Record of Decision (ROD) for the MSU (USEPA 1999) identified the remedy as a combination of dredging and capping actions. In February 2003, EPA completed the Remedial Design (RD) for cleanup of the MSU (USEPA 2003b). The U.S. Army Corps of Engineers (USACE), through an interagency agreement with EPA Region 10, is tasked to implement the remedial actions for the MSU.

The MSU encompasses specific areas of Elliott Bay and the shoreline of the former PSR facility. For design and construction purposes, the MSU has been divided into several remediation areas (RAs), as shown in Figure 1. (Note: Figures and tables are inserted after Section 9.0.) Specific features and design elements of each RA are summarized later in this OMMP. This OMMP covers operation, maintenance, and monitoring activities for all completed RAs, as well as some of the construction-related monitoring activities in RA5.

The OMMP is one of several documents that collectively make up the Pacific Sound Resources Management Plan (PSRMP). Other documents that comprise the PSRMP are the following:

- Construction Quality Assurance Plan for RA5 (CQAP-RA5) (USEPA 2004b)
- 100% Remedial Design (RD) submittal for RAs 1–4 (USEPA 2003), which includes Basis of Design Report, Plans and Specifications, and Construction Quality Assurance Plan for RAs 1–4
- PSR Cleanup Management Plan (CMP) (USEPA 2004a), which describes the administrative and testing requirements for material suitability for the cap as well as data and document control.

1.1 PURPOSE AND SCOPE OF THE OMMP

This OMMP describes physical and chemical monitoring to be completed at the PSR site over a 10-year period beginning in the 2003–2004 construction season. This OMMP includes construction monitoring for RA5 and long-term monitoring for all RAs upon remedy completion in each area. Specifically, monitoring included in this plan will evaluate (1) physical stability of the completed sediment cap, (2) physical and chemical isolation of contaminants from the biologically active zone (BAZ) (0–10 cm), and (3) construction-related progress and completion for RA5. The use of the information from the construction-related monitoring in RA5 is discussed in detail in the CQAP-RA5 (USEPA 2004b).

The OMMP sets forth specific performance standards for the planned activities to demonstrate that project objectives are being met by assessing and documenting the efficacy of the remedial actions. The OMMP also details the process for contingency monitoring in the event that performance standards are not met.

This is an adaptive plan and necessary changes will occur during EPA's 5-year review of the PSR site. Information from long-term monitoring will also be used as a basis for implementing the transition of long-term operations and maintenance (O&M) to Washington State.

1.2 SITE DESCRIPTION

The following paragraphs briefly summarize conditions at the PSR site. The RD (USEPA 2003) contains a more complete description of the MSU and an explanation of the basis of the design as related to the site conditions.

The PSR site, formerly known as the Wyckoff West Wood Treating Facility, is located on the south shore of Elliott Bay in Puget Sound, Seattle, Washington. The site is divided into two operable units: the Upland Unit and the Marine Sediments Unit. The Upland Unit consists of the former wood-treating facility that occupied an area of approximately 25 acres; the MSU encompasses approximately 200 acres of Elliott Bay and approximately 2,000 feet of shoreline. Tidal elevations range from extreme low water at –4 feet mean lower low water, National Oceangraphic Service datum (MLLW, NOS) to extreme high water at +14.8 MLLW.

From 1909 to 1994, wood-treating operations were performed at the Upland Unit. The wood-treating facility was originally a pile-supported facility over the Duwamish River estuary. The shoreline and intertidal area were filled in at various times throughout the last 100 years and the facility was eventually located on approximately 25 acres of fill material that created an upland. This in-filling resulted in a steep riprap bank on the shoreline between the upland and off-shore area.

Groundwater and soil contamination by creosote and other wood-treating waste products was present in the Upland Unit. Cleanup actions in the Upland Unit have been completed and included demolition of all on-site structures, removal of highly contaminated soil and sludge, nonaqueous phase liquid (NAPL) collection and disposal, and isolation of remaining contaminated soil and groundwater with a low-permeability surface cap and subsurface slurry wall.

Sediments in the MSU were contaminated by discharge of used and waste creosote and chemicals from the former wood-treating operations on the upland portion of the site. Chief chemicals of concern (COCs) in the MSU, described in the Remedial Investigation (RI) Report (USEPA 1998a), include polycyclic aromatic hydrocarbons (PAHs), phenolic compounds, dibenzofuran, polychlorinated dibenzodioxins and dibenzofurans (PCDD/F), polychlorinated biphenyls (PCBs), and mercury. PAHs were detected in excess of ecological screening levels down to depths of 20 feet prior to Upland Unit remediation. Downward and lateral migration of NAPL, transport of contaminated groundwater, and erosion of contaminated soils by stormwater runoff from the Upland Unit represent historical sources and transport pathways to the MSU. In addition, the former Longfellow Creek outfall historically contributed PCB and mercury contamination to the MSU from a source east of the site.

A discussion of the nature and extent of contamination in the MSU as well as risk assessment results are presented in the RI Report (USEPA 1998). Table 1 shows the COCs in sediments of the MSU as noted in the RI Report. The COCs are presented along with the full list of analytes given in the Washington State sediment management standards (SMS) (WAC 173-204).

The ROD (USEPA 1999) identified the selected remedy for the MSU as capping, with some limited dredging to maintain navigational access in a portion of the site. The extent of the capping was defined in the ROD to include all areas with sediments exceeding the cleanup screening levels (CSLs) for chemicals other than PCBs. Because of concerns for bioaccumulation and trophic effects, the cleanup value used for PCBs was the Washington State sediment quality standards (SQS). The ROD requires that the remediated area remain at or below the SQS for all chemicals.

Table 1 presents the SQS values that will be used to evaluate the suitability of imported material for capping, as well as for evaluating long-term compliance of the constructed cap with the SQS. Also shown in Table 1 are lowest apparent effects threshold (LAET) values. Consistent with typical Washington State Department of Ecology (Ecology) practice, either the organic-normalized SQS or dry-weight LAET from the table will be used depending upon the organic carbon content of the sample being evaluated (see footnote a in the table).[1]

1.2.1 Remedial Design as Related to Monitoring Objectives

Remedial area scope and designed cap composition are summarized below to aid in understanding how the monitoring objectives (MOs) apply to each RA. Refer to the RD (USEPA 2003) for design drawings, materials specifications, and explanations of the basis for design.

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[1] This approach is customary Ecology practice to determine compliance with the SQS; it is assumed to be consistent with the Record of Decision for PSR.

RA1: Intertidal/Shallow Subtidal Area

Scope. The RA1 boundaries extend from the top of the bank to the distance offshore necessary to construct grade transitions to the adjacent offshore RAs. Both the intertidal and subtidal zones experience significant erosional forces from wave action or propeller wash.

Design. Through discussions with the Natural Resource Trustees, the RA1 design includes specific grading features to maximize the areas of the cap that fall within +4 and –4 ft MLLW and to create gentle intertidal slopes that will maintain a gravelly substrate. A minimum 5-foot-thick cap will achieve final elevations within the intertidal elevations of –4 to +14.8 feet MLLW. Because of topographic variations in the intertidal area, navigational depth requirements, and the need to transition between the 5-foot intertidal cap and the offshore caps, the RA1 cap design is composed of two types of cap: a gravel cap and a thick slope cap.

The *gravel cap* is used to the maximum practical extent in the intertidal zone where moderate slopes are present. It consists of a foundation of a minimum of 2 feet of gravel mix at certain areas shown in the RD specifications (USEPA 2003); a minimum 2-foot base layer of well-graded medium to coarse sand with trace gravel and fines containing an average of 0.5 percent total organic carbon (TOC); an intermediate layer of well-graded, sandy gravel to within 6 inches of the grades shown in the RD specifications; and a top course of 6 inches of "habitat mix" (a well-graded sandy gravel). Because the intent of the ROD is that a 60-inch cap be maintained over time, an erosion allowance (12 inches) was added to the required 60 inches. This results in a minimum cap thickness of 72 inches with a 12-inch overplacement allowance.

Layer	Thickness		
Bioturbation layer	12 inches	Minimum required thickness 72 inches	Total as-placed 72 to 84 inches (thicker in some areas for grading purposes)
Erosion layer	12 inches		
Chemical isolation layer	24 inches		
ROD requirement	24 inches		
Overplacement allowance	12 inches		
Contaminated sediments			

A *thick slope cap* will consist of an armored design including a filter layer of well-graded, sandy gravel with at least 0.5 percent TOC, at least 2 feet thick; an armor layer of riprap at least 2 feet thick; a riprap "key" or toe berm at the base of the slope to provide support for the riprap; and habitat mix to fill the voids in the riprap. The latter will be added at the rate of 3 tons per 100 square feet. A minimum 42-inch cap will be placed, with a 12-inch overplacement allowance, for a total of 54 inches. The design parameters are summarized below.

Bioturbation layer	6 inches	Minimum required thickness 42 inches	Total as-placed 42 to 54 inches
Erosion layer	12 inches		
Chemical isolation layer	24 inches		
Overplacement allowance	12 inches		
Contaminated sediments			

The RA1 design is complex, consisting of several layers of materials and grades that vary by position on the shore (see the plans and specifications in the RD [USEPA 2003], particularly Plates C11–C29). In addition, after consultation with the Natural Resource Trustees, complex hard structures such as logs and root wads have been added.

For monitoring and future decisionmaking purposes, it is significant to note that the RA1 cap is constructed to the lines and grades shown on the plans, rather than to a specified minimum thickness. These lines and grades were designed to satisfy the ROD minimum thickness requirement of 5 feet, while maintaining slope stability and habitat objectives. In many areas, the desired grading results in a cap that is substantially thicker than 5 feet. Also, in designing a less armored gravel cap for habitat purposes, there is an expectation that some beach recontouring will occur from wave action in intertidal areas.

RA2a and RA2b: Shallow Nearshore Area

RA2 consists of two discrete, nearshore areas, RA2a and RA2b, which extend from approximately –15 to –50 feet MLLW. Relatively flat areas or shallow slopes with localized steepened areas characterize RA2a and RA2b. Erosional forces are minimal in the area of RA2b but significant in the area of RA2a due to propeller wash from activity of the Crowley Marine Services.

For RA2a, there will be a base layer of sand cap mix of minimum thickness 24 inches, a top layer of gravelly sand of minimum thickness 18 inches, and a 12-inch overplacement allowance. The resulting cap is summarized below.

Bioturbation layer	6 inches	Minimum required thickness 42 inches	Total as-placed 42 to 54 inches
Erosion layer	12 inches		
Chemical isolation layer	24 inches		
Overplacement allowance	12 inches		
Contaminated sediments			

In RA2b, a single-layer sand cap with a nominal thickness of 30 inches with a 12-inch overplacement allowance will be placed.

Bioturbation layer	6 inches	Minimum required thickness 30 inches	Total as-placed 30 to 42 inches
Erosion layer	0 inches		
Chemical isolation layer	24 inches		
Overplacement allowance	12 inches		
Contaminated sediments			

RA3: Navigation Access Area

This area is unique in that it is necessary to maintain navigational depths for barges, tugs, and other vessels. Because sediment contamination in this area extends to depths of 8 to 10 feet below the pre-cap mud line and because of the need to maintain navigational access, the Crowley Marine Services area will be dredged to the lines and grades specified in the RD (USEPA 2003) before the cap is placed. Because significant erosional forces may result from propeller wash, there will be a base layer of sand cap mix of minimum thickness 24 inches, a top layer of gravelly sand of minimum thickness 18 inches, and a 12-inch overplacement allowance. The resulting cap is summarized below.

Layer	Thickness		
Bioturbation layer	6 inches	Minimum required thickness 42 inches	Total as-placed 42 to 54 inches
Erosion layer	12 inches		
Chemical isolation layer	24 inches		
Overplacement allowance	12 inches		
Contaminated sediments			

Crowley Marine Services Pier (Unique Area of RA3). For this area, where clearance and steep riprap revetments are lacking, it will only be feasible to place a thin layer (6 inches) of gravel mix. Outside of the pier and at the toe of RA1 of the thick cap slope, 18 inches of gravel mix will be placed.

Outfalls. Longfellow Creek outfall is a historical overflow drainage from the creek but is not an existing salmon migration pathway. An engineered extension of the pipe extends approximately 80 feet under the RA1 cap, and the new extension daylights near the RA1/RA3 boundary at an invert elevation of –11.7 feet MLLW. A riprap splash pad extends into RA3 to prevent erosion of cap materials from the outfall discharge. Because this was a historical source of contamination to the MSU, specific long-term monitoring provisions address this outfall.

Crowley Storm Drain Outfall. This outfall is not functional and was altered.

Unidentified East Outfall. This outfall is believed to be relict and nonfunctional; it was closed by grouting with concrete.

RA4: Sloping Offshore Area

This area extends from approximately –50 to –140 feet MLLW and includes relatively steep slopes with approximately 15 to 25 percent grades. Erosional forces are minimal in this area; however, large-scale slope failures are a potential concern in the event of major earthquakes. A sand cap mix will be placed with a final minimum thickness of 30 inches. There is a 12-inch overplacement allowance in RA4. The resulting cap is summarized below.

Layer	Thickness		
Bioturbation layer	6 inches	Minimum required thickness 30 inches	Total as-placed 30 to 42 inches
Chemical isolation layer	24 inches		
Overplacement allowance	12 inches		
Contaminated sediments			

RA5: Deep Offshore Areas

RA5 consists of subareas RA5a and RA5b. These areas extend from approximately –140 to –240 feet MLLW and include slopes with approximately 4 to 15 percent grades. Erosional forces are minimal in this area. Sandy dredged material will be used to construct the cap with a minimum initial thickness of 27 inches plus a 13-inch operational allowance. Unique to RA5, approximately 3 inches of consolidation is expected within the cap material over time. The minimum post-consolidation thickness in RA5 is 24 inches. The resulting cap is summarized below.

Layer	Thickness		
Bioturbation layer	6 inches	Minimum required thickness 27 inches (24 inches following consolidation)	Total as-placed 27 to 40 inches
Consolidation	3 inches		
Chemical isolation layer	18 inches		
Operational allowance	13 inches		
Contaminated sediments			

2.0 OVERALL MONITORING OBJECTIVES

Remedial action objectives identified in the ROD (USEPA 1999) for the MSU are the following:

- Minimize human exposure through seafood consumption.
- Minimize benthic community exposure to site contaminants.

Specific monitoring objectives described in this plan are as follows:

- Determine physical stability of the completed cap to ensure that the ability of the cap to physically isolate contaminated sediments is not compromised.

- Document surface sediment quality of the cap relative to the State of Washington SQS.

The overall post-construction monitoring objective is to determine whether the cap is an effective and long-lasting remedy. The decision process will be two-tiered, with the first tier addressing identification of effectiveness or ineffectiveness. The second tier ("expanded testing" or "contingent testing") will address causes of ineffectiveness, if found in Tier 1, and is intended to provide EPA and the State of Washington with information for augmenting or altering the remedy. Data on cap performance will be synthesized to provide a complete picture of whether the cap is performing satisfactorily. Table 2 summarizes the overall objectives and specific monitoring objectives of this OMMP. The monitoring objectives will be accomplished by using the standard monitoring event schedule shown in Table 3.

2.1 PERFORMANCE STANDARDS

Biological performance standards are shown in Table 4. Physical and chemical performance standards used to assess the monitoring objectives in each RA are shown in Table 5.

Physical indicators of stability in all RAs include (1) erosion or significant movement of cap material as measured by bathymetry in intertidal and subtidal areas and (2) visual observations of the intertidal area. The decision rules for physical stability are summarized in Table 5 and described in detail in Section 6.1.

Effectiveness of the sediment cap will be based primarily on compliance with the SQS in surface sediments (0–10 cm), which is the biologically active zone and the point of compliance.

2.2 CONTINGENCY MONITORING

Figures 2 and 3 show the decision process used to implement the standard physical and chemical monitoring as well as any contingency monitoring in the event that physical or chemical performance standards are not met. Physical and chemical monitoring both contribute to the potential investigation of the mechanism of recontamination, as shown in Figure 4.

Contingency monitoring for surface sediments in excess of the SQS includes additional sediment chemistry analysis and/or biological monitoring. Contingency monitoring for significant erosion of cap material includes chemical and/or biological monitoring.

2.3 POTENTIAL CONTRIBUTORS TO REMEDY INEFFECTIVENESS

The chief contributors to potential cap failure are (1) erosion, (2) chemical permeation through the cap, (3) top-down recontamination from on-site or off-site sources, (4) large-scale movements due to either the structural failure or liquefaction of the underlying sediments, and (5) disturbance from vessel anchor drag across the cap.

Erosion from propeller scour and wind-driven waves (which may result in either cross-shore transport or long-shore transport) is a potential concern in RA1. Erosion from propeller scour is a potential concern in RA2a and RA3. An erosion-resistant layer of coarser material was included for these areas during the cap design. Erosion is not of significant concern in RA2b, RA4, or RA5. For the intertidal area and shallow subtidal area of RA1, and for all subtidal areas of RA2a and RA3, the key response to significant erosion-caused changes will be to increase the frequency of inspections and/or effect repair using upland borrow materials. An engineering reevaluation of the suitability of the material gradation would occur prior to the repair to ensure that the repairs would be resilient to forces at the site.

Chemical permeation of the cap from deep sources of contamination has been addressed in the RD (USEPA 2003) by incorporating a chemical isolation layer in the caps for all RAs. However, the appearance of contamination at the surface of the capped site would first require a determination as to whether the contamination was coming from a bottom-up direction (consistent with permeation of the cap by COCs) or a top-down direction (consistent with introduction of contaminants from another location, either within the capped area or outside of it). As discussed in Section 6, this determination will occur as a contingency, through testing of adjacent areas and sectioning cores to establish mid-core concentrations of the COCs. Should contamination be emanating from an off-site source such as an outfall or a spill unrelated to the site, the responsible party for the active source would be required to repair the cap. If it appears that recontamination is occurring by permeation or advection, this is potentially a remedy failure. A management decision would be required, which may include further investigation, placement of additional dredged material from a

USACE navigation project to increase the thickness of the cap, and/or placement of upland borrow materials.

Large-scale material movements can occur from structural failure of the subsurface sediments, and is of particular concern in the steeply sloped RA4. Large-scale sediment movements appear to have occurred historically and could occur in the future from liquefaction due to temblors. It is practical to some degree to design the remedy to avoid subsurface structural failure, and this was done during the RD. However, it is not practical to design against seismic forces above certain peak ground accelerations (PGAs). The threshold PGA causing movement is not known. The RD concluded that the February 28, 2001, Nisqually earthquake should have caused movements based upon theoretical liquefaction analysis, but no movements were discernible based upon differential bathymetric surveys. As described further in Sections 5 through 7, several methods will be used to investigate large-scale movements, and special surveys will be made when there have been PGAs on the scale of the Nisqually event or greater. If a failure is determined, the response will be to repair the cap using materials and methods consistent with the RD. It should be noted that "instantaneous" bottom-dumping techniques such as those used to construct the cap in RA5 should not be used for cap repair in RA4 because this method could trigger further slope failures.

Off-site sources of contamination affecting the cap will be considered. The only potential off-site source currently identified is the Longfellow Creek storm outfall. Special provisions for monitoring and identifying possible contamination from this source are included in the [illegible].

Disturbances from dragged anchors will be avoided by publication of a Notice To Mariners and enforcement through the U.S. Coast Guard (USCG) Vessel Traffic Service (VTS). Should cap damage be incurred by vessels that ignore this notification, enforcement would take place. Should such damage be significant enough to result in a contaminated cap surface, the potential remedies include placement of suitable gradation material and/or placement of dredged material in deeper subtidal areas.

2.4 RESPONSE MECHANISMS TO CONFIRMED REMEDY PROBLEMS

EPA and/or Washington State Department of Natural Resources (DNR) would discuss root causes and, as needed, contract for repairs or investigate potential outside sources of recontamination. The State-Superfund contract[2] will design the action and funding mechanism for cap repairs. Design and contract documents will be prepared consistent with the RD. Enforcement actions will

[2] This contract is not negotiated at this writing.

address repairs that are due to actions by others, such as spills or anchor drag. EPA, Ecology, DNR, and/or the USCG may be involved in enforcement actions.

3.0 SEDIMENT CAP MONITORING

3.1 MONITORING SCHEDULE

A 10-year monitoring schedule is presented in Table 3. EPA will be reviewing the effectiveness of the remedy at PSR no less frequently than every 5 years. These 5-year reviews will consider the monitoring results from both the Upland Unit and the MSU. The shaded columns in Table 3 indicate 5-year reviews, which are scheduled in September 2004 and 2009. EPA and/or the State of Washington will refine the monitoring program based on the monitoring results and the conclusions of the 5-year reviews.

This schedule is based on the anticipated construction schedule in the RD (USEPA 2003), which indicates completion of RA1 in the first construction season (2003–4); completion of RA2, RA3, and RA4 in the second construction season (2004–5); and completion of RA5 in the third construction season. The actual completion time for RA5 will depend on the availability of dredged material.

Table 3 contains three types of monitoring events: baseline, standard, and construction-related.

- RA1-4 Baseline. The as-built cap multibeam bathymetric surveys performed by the contractor after completion of RAs 1–4 are being used as the as-built baseline for physical monitoring in the subtidal areas. Chemical monitoring performed after the construction of RAs 1–4 is being used as the chemical as-built baseline. For intertidal areas, a baseline topographic survey will be performed by the contractor on the nearshore transect lines shown in Figure 1. Because these events will occur during construction and are thus outside the scope of this OMMP, they are not included in Table 3, although they are cited in the footnotes.

- RA1-5 Standard. The first chemical sampling to test for COCs in RA5 will occur at the first standard monitoring event in 2007–8. Assuming that construction is initiated in 2003–4, the first standard monitoring event will be performed early in the 2007–8 season to make data available for the 5-year review scheduled in 2009. Selected sampling of incidental off-site capping from dredged material placement in RA5 will also be performed at the 2007–8 monitoring event (Table 3). The next standard monitoring event is scheduled in 2012–2013. The 2012–13 event will provide data for the 5-year review scheduled in 2014.

- RA5 Construction-Related. The physical construction monitoring events that occur during construction of RA5 will be used as a baseline for RA5. Sampling for TOC in the in-place cap will also be performed in the first RA5 construction season to determine whether the TOC content of the placed cap is substantially different than the RD assumptions. Because the dredge material deposited in RA5 will be below SQS, no as-built baseline chemical event is scheduled to measure COCs.

3.2 SURFACE SEDIMENT CHEMICAL AND BIOLOGICAL CONDITIONS

The principal Tier 1 performance-related question, and the one to which the greatest weight is assigned in determining compliance with the remedial action objectives, is as follows:

- Are capped sediments in the biologically active zone (0–10 cm) remaining below the SQS?

This question is assessed under MO2a in Table 2.

If cap surface chemical concentrations are not remaining below SQS, a contingent assessment may be implemented. The primary question to be answered in the contingent assessment is as follows:

- Is the cap effectively isolating the underlying contaminated sediments?

The key associated questions are whether the post-remedy sediments are recontaminating by (1) gross physical movements, (2) bottom-up contaminant movement (by advection or permeation), or (3) top-down contamination (by deposition from an off-site or on-site source). To distinguish these conditions, sampling within the cap or along surface gradients may be necessary. This activity also falls within the context of MO2b.

3.3 PHYSICAL STABILITY MONITORING

The primary question regarding physical stability is as follows:

- Is the cap material physically stable and remaining in place at the desired thickness?

This question is assessed under MO1 in Table 2.

This question is generally subordinate to chemical/biological conditions in the biologically active zone because a cap with less thickness than the designed cap may still prove to be protective of chemical and biological effects on the biota. However, for RA3 and portions of RA1, physical changes are likely to be the only available measure for evaluating performance since these surface areas will consist of gravelly materials that will not be conducive to chemical sampling. Tier 1 testing will show whether the cap is physically stable and will supplement the chemical/biological testing. Tier 2 testing may be required if either physical or biological measures suggest a substantial physical change related to performance of the cap. For the intertidal area of RA1, annual beach inspections will be performed to determine whether seasonal, short-term (e.g., 1 to 3 years), or long-term changes occur. MO1 (Table 2) describes the testing designed to evaluate physical stability.

3.4 CAP COMPLETION MONITORING (RA5 ONLY)

Because monitoring will also address multiple-year construction progress in RA5, there are additional questions to be answered for this monitoring program:

- To what extent has capping been completed?
- Do completed portions of the RA5 cap comply with SQS?
- Are estimated volumes of dredged material sufficient to form a cap with the required thickness?
- Does the completed cap contain TOC at concentrations consistent with design assumptions?
- Are requirements of the Water Quality Certification being met during construction?

Assurance that material placed in RA5 is less than SQS will be accomplished by a suitability determination by the Dredged Material Management Office (DMMO) review of all dredging proposals. These measures are outlined in the CMP (USEPA 2004a). During the dredging and placement of cap materials, construction quality assurance will be conducted by the USACE. These quality assurance procedures are described in the CQAP-RA5 (USEPA 2004b) and are based on the assumption that the cap as placed is in compliance with SQS. The assumption will be tested in the first standard monitoring event (2007–8), which will evaluate chemical compliance of the cap.

Monitoring for water quality (dissolved oxygen, turbidity, and temperature) in accordance with the Water Quality Certification will address the environmental protectiveness component during construction (Section 5.2.2). The surface of the RA5 cap will be monitored to determine if the in-place cap contains TOC at concentrations consistent with design assumptions. Monitoring Objectives 3a (thickness monitoring), 3b (water quality monitoring), and 3c (TOC) apply (see Table 2).

4.0 MONITORING METHODS

Throughout the monitoring program, results will be compared to baseline conditions and/or the results from previous monitoring events. Based on these comparisons, trends in monitoring data will be evaluated. This section identifies the measurement methods proposed for each monitoring objective. The rationale for choosing the proposed data acquisition methods and the type of data collected by each method are also described briefly.

4.1 PHYSICAL METHODS

The principal measure of cap stability will be periodic measurements of cap elevation or thickness, including a baseline measurement that will be made following completion of material placement in each RA. Cap thickness will be determined by three methods for the subtidal area: precision multibeam bathymetry, through-cap coring (to confirm cap completion in RA5), and sediment vertical profile system (SVPS) (cap thicknesses less than 8 inches during construction in RA5 and off site following completion of the entire cap). An additional method (sub-bottom sonar profiling) has been included in the program as a possible cost-effective contingency, although this method has limitations that may preclude its use. Visual inspection and photography at set points on the beach combined with topography will be used to identify significant changes in cap thickness in the intertidal zone.

Due to limitations on precision at depths (see Section 5.2), bathymetry will be most useful in RAs where the sediment surfaces are generally higher than –100 feet MLLW. This includes RA1, RA2, RA3, and the shallower portion of RA4. For these shallower areas, confirmation of cap thickness through differential bathymetry is an objective of the surveys.

For the portions of RA4 and RA5 with bottom elevations below –100 feet MLLW, precision bathymetry will also be used as a means of verifying that the cap is in place. The bathymetry results for areas with bottom elevations deeper than –100 feet MLLW will be used to distinguish large features, such as slope failures. Also, if the precision errors of bathymetry at the time of the survey allow reliable differential calculations, cap thicknesses may be calculated for these deeper areas. Because no erosive forces (other than potential large-scale landsliding) are expected in the deeper areas, the objective of the bathymetry surveys for areas with bottom elevations deeper than –100 ft MLLW is to confirm that no substantial morphological changes have occurred.

Through-cap coring to determine cap thickness may be used as a contingent action in areas with bottom elevations below –100 feet MLLW.

4.1.1 Horizontal Positioning

A precision Differential Global Positioning System (DGPS) will be used to record all sediment sampling locations to a horizontal geodetic accuracy of positioning of ±1.0 meter. Real-time kinetic positioning is required to meet vertical positioning accuracy without in situ reference points within the survey area. Sampling location data will be acquired in the state plane coordinate system (North American Datum (NAD) 83/91, Washington North Zone) in feet.

4.1.2 Bathymetry and Vertical Positioning

The vertical datum used for measuring depth data will be feet referenced to mean lower low water (MLLW, NOS). Precision bathymetry provides information on the depth of substrate below a tidally-corrected water level. Bathymetric data are collected by transmitting a sound pulse from a shipboard transducer and monitoring the seafloor-reflected signal. When the speed of sound in seawater is known, the distance of the seafloor from the transducer can be calculated. By collecting multiple soundings in a closely spaced lane grid, bathymetric data can be used to produce a spot elevation map or a contour map at user-defined contour intervals. By comparing successive bathymetric surveys, changes in seafloor elevation (i.e., cap thickness) can be measured. For measuring cap thickness, precision bathymetry is considered preferable to more intrusive methods such as coring because it is faster, is less expensive, provides nearly continuous coverage, and does not affect the physical integrity of the cap. Precision bathymetric surveys can also detect slope failures that occur during or after cap placement.

There are two general types of bathymetry, single beam and multibeam. Single-beam surveys, which have been traditionally used for bathymetric confirmation of cap placement, are conducted on linear track lines typically spaced at 50 to 200 feet. Single-beam surveys are limited in that they do not provide data between the track lines and cannot provide data under surface obstructions. However, points can be placed close together along the track lines, potentially giving detailed information along the track lines. In contrast, multibeam surveys offer complete coverage of all bottom features and can provide coverage under piers, barges, or other obstructions. For the OMMP, multibeam surveys were selected due to the amount of coverage needed and the potential to identify slope features in RA4.

Multibeam surveys will be acquired by the construction contractor to provide baseline mapping after completion of RAs 1–4. A multibeam bathymetry survey will also be performed on the entire cap upon completion of RA5.

Differential bathymetry is an analysis of the apparent differences in elevation between two surveys. To maximize comparability and make meaningful estimates of changes in elevation, it is necessary to minimize inter-survey errors. Use of the same vertical control procedures in successive surveys is critical in this regard.

4.1.3 Through-Cap Coring

To confirm construction completion, through-cap cores will be the primary method to determine cap thickness in RA5. Conventional boring techniques, vibracore samplers, and a variety of gravity coring devices may be suitable. However, site-specific factors such as the layering of the deposit (e.g., sand cap over relatively soft material), cap material properties, and the capability of a coring technique to collect samples from such deposits should be considered when selecting a coring technique. Cores will be inspected to determine the thickness of cap. All cores will be photographed, measured, and logged. Samples may be archived for future chemical sampling.

4.1.4 Sediment Vertical Profile System

SVPS is a tool that can be used to detect thin layering within sediments. The SVPS device consists of a video camera and an optical prism mounted on a submersible frame that is lowered to the bottom. The prism is driven by gravity into the sediment, penetrating to a depth of up to 15 to 20 cm. The camera is activated when the device hits the bottom and obtains a sediment profile photograph. The image can provide information regarding sediment layering and benthic activity. SVPS can be used to rapidly collect data (about 100 images per day) and provide evaluated results within 24 hours.

Since SVPS can measure material deposits ranging from only 1 mm to 20 cm (8 inches), it will be used in conjunction with other methods to define the full range and extent of deposit thickness. The SVPS will be used primarily for mapping the extent of the flanks of cap deposits around dredge lifts deposited in RA5. SVPS will also be used to map the extent of off-site transport after completion of the RA5 cap.

Because SVPS provides high-resolution visual documentation, it produces a variety of information in addition to cap thickness that may be useful to the project. The depositional layer thickness is visually evident because of its unique optical reflectance, color, and/or grain size. Also, stratification of the cap material itself can be evaluated (such stratification occurs due to the slower settling of finer grained cap particles).

Other SVPS information that may be useful for long-term cap monitoring includes benthic successional infaunal stages, a measure of benthic community restoration. The SVPS images can be evaluated to determine whether a relatively healthy or undisturbed benthic habitat quality exists. However, this measure is not a key decision point in the OMMP and may not be used for decisionmaking.

4.1.5 Topographic Surveys

Typically, intertidal elevation surveys measure long-term changes due to long-shore and cross-shore sediment transport, other extended physical processes, and large changes due to short-term major physical events such as intense storms. Beach elevations in the intertidal zone will be measured through topographic surveys conducted in the baseline and standard monitoring events (Table 3) and may also be measured after major physical events or physical disasters. Beach elevations on designated transects will be measured and the baseline event will be compared to subsequent monitoring events to ascertain changes in cap thickness.

4.1.6 Operation and Maintenance (O&M) Beach Inspection

Beach walks will be undertaken annually at tides of −1.5 feet MLLW for the entire length of the accessible beach to provide the following information:

- Logged visual observations of material accretions or erosion, as well as notes of any debris that might over time cause excessive erosion in specific areas.
- Photographs taken from fixed points of reference at least every 200 linear feet and photographs of any additional features that would indicate significant changes to the beach. In the event of major cap thickness changes, the photographs will be used with the topographic surveys to help ascertain the cause of the cap changes.
- Record of distressed or dead biota.
- Special beach inspections if seismic events occur (see Section 6.1.3).

An initial post-construction beach inspection will be made along with the baseline topographic survey and will occur annually thereafter. Beach inspections may also be scheduled following major physical events such as large or unusual storms.

The USACE will retain an "environmental support" contractor to accomplish several of the monitoring activities; this contractor will plant forbs and shrubs along the graded beach and maintain them for a minimum of one season to ensure establishment of a plant community. During the first year, therefore, the beach inspection will also quality-assure the contractor's work. This revegetation activity is a hybrid of construction and long-term monitoring; it is described in CQAP-RA5 (USEPA 2004b) because it will also be overseen by the Engineering During Construction team involved with the RA5 cap.

4.1.7 Sub-Bottom Profiling

This technique is a downward-looking sonar method that distinguishes layers of different acoustic reflectivity in the sediment. At some sites, the cap material has been of sufficient contrast to the sediment below so that this method has provided a convenient and cost-effective means to determine the thickness of the cap. However, in 1992–3 at the Wyckoff/Eagle Harbor Superfund Site, the USACE found that the technique may not be able to resolve cap thickness when layers of biogenic gases appear. The suite of contaminants at that site is very similar to that at PSR, although PAH concentrations in RAs 4 and 5 are below those at Wyckoff/Eagle Harbor. Similar experience at other sites has shown that sub-bottom profiling is ineffective at distinguishing cap thickness when the cap material is physically similar to the underlying sediment, which may be the case in RA5 or elsewhere in the MSU.

Accordingly, this technique is considered to be a contingent one that would require validation against cores and bathymetry for this site. Should sub-bottom profiling be used, cap thickness would be measured and digitized from the electronic sonar records. Changes in seafloor elevation documented using precision bathymetry would be cross-checked against cap thicknesses measured with sub-bottom sonar. Sub-bottom sonar and precision bathymetry would be a paired dataset to document both the surface relief and thickness of the cap. Deeper cores would be the means of calibration.

4.2 CHEMICAL/BIOLOGICAL METHODS FOR SEDIMENT

4.2.1 Grab Samples (Chemistry/Biology)

Most surface sediment samples will be taken with grab samplers. Sediment grabs will be collected from the biologically active zone (0–10 cm). For the samples collected from RA5 during the first construction season, only TOC will be analyzed for. For the samples collected during the standard monitoring events and any expanded sampling, surface sediments will be chemically analyzed and compared to SQS values. At the first 5-year review, it may be possible to reduce the list of chemical parameters shown in Table 1. If the concentrations are above SQS but below CSLs, biological tests discussed in Section 4.2.4 may be performed as a contingency to determine whether biological SQS requirements are satisfied.

4.2.2 Through-Cap Coring (Chemistry)

Through-cap coring and subsequent chemical analysis are intended to be a contingent monitoring action, used only when surface recontamination is observed in surface samples. Through-cap cores will provide a core sample through the cap and into the native sediment. Once the native sediment/cap material contact is discerned and the cap thickness measured, sediments will be visually inspected for evidence of physical mixing between the underlying native material and the overlying clean cap material. The core will be sectioned to provide a mid-level sample for comparison with surface concentrations to determine the potential source of the contamination (see Figure 4). It is noted that through-cap coring with typical vibracoring equipment may not be feasible in certain locations where cap material gradation is coarse. Alternative coring methods (such as hollow-stem auger) may be considered if coring is determined to be appropriate.

4.2.3 Chemical Parameters

Sediment "Conventional" Parameters

Conventional parameters are required to provide information to aid in interpreting chemical and biological tests. Sediment conventionals measured in all chemistry and biological sampling events include the following:

- Grain size
- TOC
- Percent solids (total solids)

Sediment conventionals measured to support biological analysis (as a contingency only) include the following:

- Total volatile solids (TVS)
- Total sulfides
- Ammonia

Analysis of total solids, TVS, and total sulfides will follow the *Recommended Protocols for Measuring Conventional Sediment Variables in Puget Sound* (PSEP 1986). Ammonia analysis will be conducted according to standard EPA/USACE procedures (Plumb 1981). For TOC determinations, see Bragdon-Cook (1993), paraphrased in the following sentences. SW-846 Method 9060 will be used because it provides for more sensitive measurement of TOC concentrations in sediment than the PSEP method; it can detect TOC in sediments below 0.1 percent. The corresponding total solids analysis should be run twice, once at 70° C and once at 104° C, and the TOC calculation based on dry weight at 104° C.

Grain size will be determined using PSEP (1986). The following sieve series will be used: numbers 4, 10, 18, 35, 60, 120, 230. The fine-grained fraction must be classified by phi size (+5, +6, +7, +8, >8). TOC is also used in evaluating the chemical analysis.

Sediment "Chemical of Concern" Parameters

As stated above, the list of analytes for full characterization of the capped area is subject to reduction in several parameters based on results of the construction and OMMP monitoring.

- EPA SW-846 Method 8082 PCB. Method 8082 will be used to measure total PCBs, with Method 3510C used to prepare extracts, followed by analysis by a gas chromatograph equipped with a dual electron capture detector.

- Method 8270c (semivolatile organics). Method 8270c will be used to analyze all organics other than PCBs, with Method 3550b used to prepare extracts.

- Method 6010C/7470A (metals). Method 6010C (inductively coupled plasma) will be used to measure arsenic, cadmium, chromium, copper, lead, and zinc. Method 7470A (cold vapor atomic absorption) will be used to analyze for mercury.

At a minimum, the laboratory should meet the requirements specified by the Washington State Department of Ecology for both chemical and biological testing. These requirements can be found on Ecology's web site at http://www.ecy.wa.gov/programs/tcp/smu/sapa/ch7.doc. Tables 9 through 12 are taken from this site with minor changes.

4.2.4 Bioassays and Benthic Measures

Bioassay tests are a contingent action; that is, EPA and State coordination will occur before bioassay tests are undertaken. Should chemistry levels fall between SQS and CSL in the grab samples, biological testing could be used to confirm whether a biological effect is realized. At concentrations higher than the CSL, bioassays will not be performed. See the *Puget Sound Protocols and Guidelines* (PSEP 1995) and the Dredged Material Management Office homepage: http://www.nws.usace.army.mil under "Dredged Material Management" for bioassay testing references.

The standard suite of bioassays may be triggered by meeting or exceeding one or more chemical SQS concentrations in surface sediments during monitoring. Bioassays need to be performed within maximum holding times (40 days from collection). Therefore, remobilization of sampling crews will be required for any biological testing. The following is the list of standard bioassays and benthic community measures specified in the SMS, with changes registered in the Sediment Management Annual Review Meetings of the Dredged Material Management Program (DMMP).

Ten-day amphipod acute mortality test. For appropriate species selection, consult the DMMP. For test interpretation, see Table 4.

- *Rhepoxynius abronius*—preferred species for coarser grained sediments (i.e., fines <60 percent)

- *Ampelisca abdita*—may be used if test sediment contains >60 percent fines.

- *Eohaustorius estuaries*— may be considered for use in grain size distributions ranging from 100 percent to 0.6 percent sand, as long as the clay fraction is <30 percent, and in interstitial salinities ranging from 2 to 28 parts per thousand (ppt).

Twenty-day juvenile infaunal growth test

- *Neanthes arenaceodentata* (Los Angeles karyotype)

Sediment larval test. The DMMP may be consulted for assistance in selecting appropriate species. For test interpretation, see Table 4.

Echinoderm

- *Dendraster excentricus*—recommended species
- *Strongylocentrotus purpuratus*—acceptable species
- *Strongylocentrotus droebachiensis*[3]

Bivalve

- *Mytilus galloprovincialis*—recommended species
- *Crassostrea gigas*

Benthic community analysis (abundance of taxa)

- Deploy trawls at the site and at a Puget Sound reference station, executed according to the PSEP (1986) guidelines.

- Calculate mean abundance of each of these faunistic classes at PSR site with respect to a reference site: Crustacea, Polychaeta, Mollusca.

[3] May be substituted if test sediment contains greater than 60 percent fines.

- Less than 50 percent of reference taxa is considered an impacted community.

4.2.5 Field Water Quality Measurements

Water quality measurements are required by the Water Quality Certification. The following will be measured:

- Nephelometric turbidity: Measured in field with turbidity meter, according to Standard Method 2130 or equivalent (APHA 1971)
- Dissolved oxygen: Measured in field by membrane electrode according to Standard Method 4500 or equivalent (APHA 1971).
- Temperature: Measured in field by mercury thermometer or thermometer of equivalent accuracy.

5.0 MONITORING AREAS

The five remedial areas described in Section 1.2.1 were used for remedial design. These RA designations have less utility after construction is completed. After construction of the site-wide cap, the site can still be seen as five areas, but each represents a particular monitoring regime[4]. These regimes are shown in Table 5 and are categorized as follows:

- RA1, intertidal zone, following construction
- RAs 1–5, subtidal subtidal, following construction
- Area Around Longfellow Creek Outfall, following construction
- Off-site Incidental Capping Area, following construction
- RA5 during construction

This section explains which monitoring method described in Section 4 will be used in each monitoring area.

5.1 INTERTIDAL RA1, FOLLOWING CONSTRUCTION

Monitoring in the RA1 intertidal area will rely primarily upon physical measurement techniques (land surveying and photography at fixed stations) as the determinant of compliance. Chemical analysis on the surface of the intertidal cap will be limited because of the gravel cover on top of the cap. Chemical surface samples will be feasible only in places where finer material is present on the intertidal cap.

5.1.1 Physical Monitoring

The topographic survey will be taken on transects located 100 feet apart, as shown in Figure 1. The transects will originate at the shoreline and extend out into Elliot Bay through the intertidal zone to approximately -1.5 feet MLLW (Figure 5). Photographs will be taken from the waterline at a known elevation while looking toward the shoreline. Multibeam bathymetry may be used in water to about -1.5 feet MLLW when accomplished on a high tide. (See next section for discussion of measurement quality objectives [MQOs] and data quality indicators [DQIs] for bathymetry.)

[4] RA1 and RA3 have a top gravel layer, which will not allow chemical surface sampling unless finer grain materials are present on top of the cap. However, the chemical and biological tests and the physical measurement methods are the same as those for RA2 and RA4 (depths less than 100 feet). It is expected that the number of locations where samples can be collected will increase with elapsed time after the remediation due to deposition of fine materials on the capped areas.

MQO for Topographic Survey: Horizontal, 3-foot precision; vertical, 0.1-foot precision.

DQI for Topographic Survey: Each survey will make repeated measurements at a nearby monument or identifiable physical feature. Precision should be within the tolerances stated in the MQOs.

5.1.2 Chemical/Biological Monitoring

No chemical/biological monitoring is planned for the intertidal area because the gravel layer of the intertidal cap is too coarse for chemical and biological testing. However, if fine material is present on the intertidal cap, samples may be collected and the MQOs and DQIs shown above utilized.

5.2 SUBTIDAL RAs 1–5, FOLLOWING CONSTRUCTION

The subtidal portion of the site after completion of cap placement requires two testing regimes for determining cap thicknesses. Bathymetry currently measures seafloor elevations with sufficient confidence for estimating cap thickness only to a water depth of approximately −100 feet MLLW because of instrument limitations, pitch and yaw of the vessel during the survey, and intersurvey errors. Accordingly, precision bathymetry will be used for RA1, RA2, and RA3 (water depths generally less than −50 feet MLLW), and at depths up to approximately −100 feet MLLW in RA4.

In water deeper than −100 feet MLLW in RA4 and in water depths of −140 to −240 feet MLLW in RA5, bathymetry will be used primarily for distinguishing large features such as slope failures. Because no erosive forces (other than potential large-scale landsliding) are expected in the deeper areas, the objective of the bathymetry surveys for areas with bottom elevations deeper than −100 ft MLLW is to confirm that no substantial morphological changes have occurred.

5.2.1 Physical Monitoring

5.2.1.1 Bathymetry

Multibeam bathymetry from the construction of RAs 1–4 will be used as a baseline for bottom elevations; subsequent multibeam surveys taken during the O&M monitoring will be compared to the baseline to determine cap thickness changes. The results will be used to map the post-construction cap changes. Table 3 shows the frequency of sampling events. Multibeam surveys will be conducted using a small research vessel capable of operating in water depths of 5 feet or shallower. The following activities are included:

- Survey planning and delivery, and mobilization of equipment
- Acoustic surveys on cap as required
- Installation of recording tide gage if not already established
- Post-processing and QC of collected acoustic data
- Preparation of georeferenced survey plots, including contouring and digital terrain modeling

MQOs for Bathymetry: Single-survey precision is 0.5 percent of depth (equivalent to 0.7 foot between-survey precision at 100 feet of depth). As discussed above, multibeam bathymetry will be performed for all RAs. However, bathymetry data will not be used in areas deeper than 100 feet below MLLW as a primary determinant for cap thickness because the measurement error at these depths may be excessive. That is, the minimum detectable difference of 0.3 foot is exceeded below the 100 feet MLLW water depth. Bathymetry will be used, however, as part of a weight-of-evidence approach at depths >100 feet.

DQIs for Bathymetry: Multibeam precision will be confirmed at least twice during a survey by repeated measurement of an area 100 by 100 feet and preparation of a difference chart. If differences of greater than 1 foot in an area 25 by 25 feet occur in this analysis, the data will be evaluated for usability.

The survey will be performed in accordance with the QC and QA criteria listed in Table 11-2 of USACE (2002).

5.2.1.2 Through-Cap Coring

Through-cap coring is a contingent action only, to be used should surface sediment chemistry testing for MO2a (sediment compliance with SQS) indicate exceedances.

MQOs for Through-Cap Coring: As discussed, through-cap cores will be used as a contingent action only. The MQOs for coring are (1) penetration through the cap into the sediment below and (2) the ability to visually distinguish the old sediment from the cap.

DQIs for Through-Cap Coring: Logging of the core will include inspection for evidence of compression and "smearing" along the outside of the core. Penetration of the cap into the former sediment horizon is the qualitative DQI for coring. Measurement of the cap thickness will begin at the upper margin of the visibly mixed layer.

5.2.2 Chemical/Biological Monitoring

Sampling units for surface grabs and cores for the standard and expanded monitoring events are discussed in Section 6. Per Table 3, the baseline monitoring event performed after completion of

RAs 1–4 and the first standard monitoring event of RA5 will sample and analyze for the compounds listed as COCs in Table 1, with the exception of PCDD/F. PCDD/F are not included in the Washington State SQS for ecological effects. The ROD indicated that both PCB and PCDD/F are COCs for human health but did not develop a specific human-health protection cleanup goal for PCDD/F. Instead, the ROD references the area mean background concentration of 1.052 ng/kg toxicity equivalency quotient TEQ (dry) for PCDD/F. Existing information on concentrations in the Duwamish River suggests that the river sediments contain low ng/kg TEQ. Accordingly, concentrations of PCDD/F should not be much different from area background and therefore are not proposed for analysis.

Reducing the list of required analytes may be considered based on the contaminant detection frequencies and concentration levels during construction and post-construction monitoring.

It is noted that chemical analysis on the surface of the RA1 subtidal and RA3 caps will be limited because of the gravel cover on top of the cap. Chemical surface samples will generally be feasible only in places where finer material is present on the cap.

In addition to the chemical/biological monitoring performed during the first standard monitoring event, surface samples will be collected for TOC analysis on the RA5 cap following the first RA5 construction season to determine if the TOC content of the placed cap is consistent with design assumptions.

Chemical MQOs for Sediment Monitoring: Table 8 shows the MQOs for each of the identified COCs, TOC, and also for other standard SQS. The MQOs are generally developed by setting the desired sensitivity to 70 percent of both the organic carbon (OC)-normalized SQS at 0.5 percent OC and by using the dry-weight equivalents of the SQS (generally, the lowest apparent effects thresholds [AETs]). Shading indicates the MQO for each chemical. A comparison is also made to typical method quantitation limits (at and above which a value is reported as a number with confidence) and method detection limits (at and above which a compound is confirmed to be present). Between these two limits, values are reported as estimates. For the PAHs, the values in bold type in the right-hand column of the table indicate PAHs for which the laboratory must take special care.

Chemical DQIs for Sediment Monitoring: Tables 9, 10, and 11 describe precision, accuracy, calibration procedures, and quality control for the methods being used.

Chemical MQOs for Water Quality Monitoring:

- The turbidity meter should be capable of measuring ±3 NTU in the range of 5 to 50 NTU, and 5 percent of turbidities above that. These values were determined to provide a reading that is 30 to 50 percent of the threshold decision value.

- The dissolved oxygen meter should be capable of measuring ±0.3 mg/L in the range of 0 to 10 mg/L. The water quality requirement is a dissolved oxygen concentration of greater than 6 mg/L, or greater than 0.2 mg/L below background if background is <6 mg/L. The 0.3 mg/L precision will meet the 6 mg/L decision but not the 0.2 mg/L if the background is below 6 mg/L. A more sensitive instrument may be available, but this will not likely be necessary because dissolved oxygen in open water in Puget Sound is usually well above the 6 mg/L value.

Chemical DQIs for Water Quality Monitoring:

- Dissolved oxygen meters and turbidity meters should be calibrated daily with a range of 3 standards across the span of interest.

Biological MQOs for Sediment Monitoring: Table 4 shows test interpretations and data quality indicators, and the cited protocols have minimum organism acceptance criteria. Table 12 describes QC conditions for performing the tests.

5.3 AREA AROUND LONGFELLOW CREEK OUTFALL, FOLLOWING CONSTRUCTION

Flow from Longfellow Creek has been rerouted to the West Waterway of the Duwamish River. In the MSU, the Longfellow Creek overflow outfall remains functional and receives local storm drainage and periodic peak overflow from Longfellow Creek. Historically, this outfall carried PCB and mercury contamination to the sediment. Focused chemical sampling around the area of the outfall will ensure that cap recontamination from this potential source will be identified if it is occurring.

5.3.1 Physical Monitoring

Physical testing will be the same as for other shallow subtidal areas.

5.3.2 Chemical/Biological Monitoring

Chemical testing locations are shown in Figure 5. Grid A6c3 is designated "reference" to determine broad-area changes that are not due to the outfall. This information, along with comparison of the results from each location to SQS, will be used to determine whether the outfall may be contributing contamination to the sediment. The designated locations may not have sufficient fines content for chemical analysis. In this case, the locations will be field-determined by moving radially outward from the outfall until a suitable substrate is recovered in the sampler.

5.4 OFF-SITE INCIDENTAL CAPPING AREA, FOLLOWING CONSTRUCTION

Incidental capping of off-site areas containing chemicals that currently fall between SQS and CSLs will occur during placement of dredged material in RA5. The ROD considered these areas for full remediation and made the decision that they would not be part of the site; however, it is believed that they will benefit from the remedial action. Chemical surface samples will be collected after completion of the RA5 cap to determine if off-site remediation may be occurring. Also, the areal extent of the incidental off-site cap will be determined through SVPS after the RA5 cap is completed. No remedial performance standards exist for chemical/biological recovery. However, it is possible that chemical concentrations in these areas may drop to near or below SQS due to incidental capping.

5.4.1 Physical Monitoring

After completion and verification of the desired cap thickness throughout RA5, physical monitoring of the adjacent areas will be conducted by SVPS centered on a distance of 300 feet to the east and west and 800 feet to the north from the boundary of the capped area (these distances may be altered depending on SVPS measurement of the actual lateral spread of the off-site cap). An example of the expected results from the survey is included in Figure 6, which is a similar survey for the disposal site at Commencement Bay. There is no associated performance standard for this monitoring, but it will demonstrate the spread of cap material to these adjacent areas. The area within the designed cap boundaries will not be sampled by SVPS, which does not have enough penetration to provide useful information there.

MQO for SVPS: It is intended that the cap/sediment interface be discerned within the SVPS prism's penetration. Conditions that might deter this situation are (1) depths of incidental cap greater than 8 inches and (2) insufficient penetration of the instrument. The former may be managed by moving farther away from the boundary; the latter may be managed to some extent by increasing the weight on the instrument.

DQI for SVPS: To generate usable data, penetration of the SVPS prism should be at least 4 inches into the substrate. Otherwise, the operator should increase the weight on the instrument.

5.4.2 Chemical Monitoring

The objective of the off-site chemical sampling is to determine whether the incidental capping has resulted in surface concentrations below the SQS. After completion of the RA5 cap, seven surface grab samples in grids approximately 300 feet outside of the site boundary will be collected and analyzed to determine the sediment chemistry outside the design cap area. The proposed locations are shown on Figure 5. There is no associated performance standard, but this monitoring will demonstrate whether incidental capping succeeded in reducing values of PAH to below SQS levels. For MQOs and DQIs for chemical monitoring, see Section 5.2.2.

5.5 RA5 DURING CONSTRUCTION

SVPS and through-cap coring will be used in RA5 to determine cap thickness progress during construction. Once completed, RA5 will join the monitoring of the other subtidal areas.

5.5.1 Physical Monitoring

During construction, physical monitoring events using through-cap cores and/or SVPS will be performed after each construction season. The subareas of RA5 that have achieved the desired dredge cap thickness will be moved into the long-term monitoring program. After the last subarea of RA5 is completed, physical monitoring of this subarea and selected off-site locations (Figure 5) will be conducted. A baseline multibeam survey of RA5 will be conducted when RA5 is completed. This may be deferred until the next scheduled monitoring event. The next monitoring event for the entire RA5 cap will be in 2007–8 to provide data for the 5-year review scheduled in 2009.

MQO and DQI for Through-Cap Coring: See Section 5.2.1.2.
MQO and DQI for SVPS: See Section 5.4.1.

5.5.2 Chemical/Biological Monitoring

The only chemical/biological monitoring scheduled during construction on RA5 is selected sampling on the cap surface for TOC after the first construction season. Four samples will be taken at the end of the first construction season to verify that the TOC of the in-place cap is consistent with design assumptions. For MQOs and DQIs for the TOC monitoring, see Section 5.2.2.

6.0 SPECIFIC MONITORING OBJECTIVES

Decision rules are provided to ensure that later DQO steps will successfully resolve the key decisions. The decision rules derive from the three monitoring objectives described in Table 2. Table 5 summarizes the decision rules. Overall logic for the monitoring program is displayed in Figures 2 through 4.

6.1 PHYSICAL MONITORING—MONITORING OBJECTIVE 1

Monitoring Objective 1 is to *determine the physical stability of the cap*. Table 3 describes a "basic" monitoring scheme, using topographic and multibeam bathymetric survey techniques and/or through-cap coring to identify significant variations from the as-built cap thickness. The near-tidal transect lines for the topographic survey are shown on Figure 1.

6.1.1 Physical Monitoring Decision Rules

The key decision points for *thickness* loss of cap material in subtidal and intertidal areas are described below. The size of a significant *area* of change is left to best professional judgment (described below), because comparisons among monitoring events will depend upon the inferred source of measured variation and the slope.

6.1.1.1 Subtidal Areas

For subtidal areas, the key decision point for thickness loss of the capped area is approximately 1 foot. If a decrease in cap thickness of >1 foot is measured, the possible causes are (1) regional erosion or minor material movement, or (2) massive failure. The former could imply failure of the remedy (due to erosion or localized shallow slope failure) and suggest a management decision for cap repair. For this scale of failure, a depth change in excess of approximately 1 foot, over an area of greater than 10,000 square feet, has been subjectively determined to be the decision threshold for physical map differences.[5] Difference plots will be generated from successive multibeam bathymetric events, and best professional judgment will be exercised in determining this threshold. A 1-foot cap loss will not necessarily require recapping, but would be the trigger for possible further investigations and potential management decisions that may include recapping.

[5] Note that this decision rule involves a greater area than the data quality indicator—used for determining instrument resolution—of a 25- by 25-foot area (Section 5.2.1.1).

6.1.1.2 Intertidal Areas

RA1 is an intertidal and subtidal area that is capped to a minimum of 5 feet thickness as required by the ROD. The RD states that "the intent of the ROD is that a 60-inch thickness be maintained in the intertidal area over time . . .." Thus, the intertidal cap includes a 2-foot isolation layer plus a 3-foot armor (including overplacement for operational constraints) layer. In some places, more than 5 feet of total cap have been placed in intertidal areas to conform to the design grading plan. Accordingly, the depth at a given point to the 2-foot isolation layer is not constant.

For the intertidal areas in RA1, some beach recontouring by the tides is expected, and a loss of >1 foot in cap thickness needs to be considered in light of the overall stability of the beach and the actual constructed cap thickness in the area of loss. Therefore, decision points (considering absolute loss and/or trends in losses) are needed to define conditions of either (1) unacceptable losses, indicating possible imminent failure of the remedy and the need for immediate corrective action, or (2) marginal losses, which may require more intensive monitoring or maintenance.

Unacceptable Losses. The bright-line threshold for immediate maintenance and repair would constitute any exposure of the isolation layer of the cap. This is a layer of well-graded, medium-to-coarse sands with trace gravel and fines. The overlying armor material is a gravel (D_{50} = 18 mm). Exposure of the sandy isolation layer should be visually distinctive and would occur only if greater than 3 feet of cap loss occurred. Depending upon the location, substantially more than 3 feet of cap loss would be required to expose the isolation layer. Cap losses greater than 3 feet may not indicate remedy failure, but instead suggest that there is a need to redesign and replace the armor layer.

Marginal Losses. The survey transects will be used to determine trend-line losses of material. Unlike the bright-line threshold (exposure of the isolation layer), smaller cap thickness losses occurring sequentially could be cumulatively significant if the direction continues to be loss. A decision rule of greater than 1 foot of loss per survey period for two successive survey events, or any cumulative loss greater than 3 feet would trigger an engineering evaluation and, as appropriate, more intense monitoring or maintenance. The visual beach inspections and photodocumentation will aid in evaluating the survey information.

6.1.2 Approach for Physical Monitoring—Areas Shallower Than –100 Feet MLLW

Within-survey precision for multibeam bathymetric measurements is approximately 0.5 percent or better (USEPA 2003), although technological advances may improve this in the future. Therefore, the survey precision will be approximately 0.5 foot in water 100 feet deep beneath the vessel. However, the calculation of error *between* surveys requires one to multiply single-survey precision by the square root of 2 (or 1.4). In 100 feet of water, 0.7 foot, or 8 to 9 inches, is the current estimated limit of resolution between surveys. Selecting an arbitrary 30 percent minimum detectable difference to bound decision errors, 100 feet of water is as deep as paired, multibeam bathymetric surveys can discern a 1-foot difference in cap thickness with confidence. Thus, in areas with bottom elevations above –100 feet MLLW, differential bathymetry is considered adequate to determine physical stability of the cap under MO1.

In intertidal areas, topographic surveys (using standard land surveying methods on predefined transects) will be conducted, along with visual inspections and photodocumentation. These methods are considered adequate to determine physical stability of the cap under MO1. It should be noted that some long-term (secondary) settlement of the underlying sediments in RA1 is expected, estimated at several inches over about 10 years. This is might need to be considered in interpreting the intertidal survey results.

6.1.3 Approach for Physical Monitoring—Areas Deeper Than –100 Feet MLLW

The maximum water depth in RA4 is approximately -140 feet MLLW, and RA5 extends as deep as -240 feet MLLW. Multibeam surveys will cover all cap areas; however, in areas with bottom elevations below -100 feet MLLW, the intersurvey precision may not be able to discern cap thickness changes of 1 foot or less. This is considered acceptable because of the following:

- Below –100 feet MLLW, current measurements and propwash monitoring do not indicate any potential for cap erosion caused by currents.
- The only identified mechanism for cap loss at these depths is submarine landsliding, which can be visually identified as morphological changes in the multibeam survey plots. (These are best visualized by processing the survey data to produce plots of bathymetric contours overlain by a digital terrain model.)
- Standard chemical monitoring (MO2a) will verify that the cap surface is chemically clean.

Therefore, in areas with bottom elevations below –100 feet MLLW, an absence of morphological changes in the multibeam survey plots, combined with acceptable results of the standard chemical monitoring (MO2a), is considered adequate to determine physical stability of the cap under MO1.

During RD (USEPA 2003), an estimate was made on mode of slope failure. It showed evidence of massive historical landslides, presumably as a result of liquefaction of the former deltaic sediments underlying the cap. A similar mode of failure of the slope may indicate a need to repair the cap, but it would not indicate a "failure" of the remedy, because the RD determined that the cap could not feasibly be engineered to avert this kind of movement. For this scale of movement, deep

(>3 feet) and large (more than 10,000 square feet) changes in the bottom would be expected and would readily be identified in the multibeam survey plots.

6.1.4 Approach for Physical Monitoring—Contingent Methods

A decision rule for initiating a special survey is tied to seismic sensors in the area and bathymetric observations. Should (1) a seismic event (dry-land measure at Harbor Island seismic station of peak ground acceleration equal to or greater than 0.12 gravities) or (2) slope changes indicated by bathymetry or coring occur, a special (previously unscheduled) multibeam bathymetric survey may be performed. In addition, unscheduled beach inspections may be made after either a seismic or a significant storm event. A significant storm event for PSR is considered one with sustained winds from the northwest to northeast with speeds greater than about 15 to 20 mph.

For deeper areas (>100 feet below MLLW), survey results that identify morphological changes suggesting landsliding or chemical exceedances under MO2a will trigger contingent through-cap coring as the definitive confirmation measure of cap thickness and chemistry (in a contingent monitoring event). The coring array is described in Section 6.2.1. In these deep areas, the addition of sub-bottom profiling will be considered for addition to the program after the first round of sampling results and consideration of as-built information.

6.2 CHEMICAL AND BIOLOGICAL TESTING—MONITORING OBJECTIVES 2A AND 2B

6.2.1 Standard Sediment Testing (MO2a)

Figures 3 (standard and expanded testing) and 4 (contingent source investigation testing) address the decision logic under MO2a: *Determine compliance of the surface of the cap with SQS.*

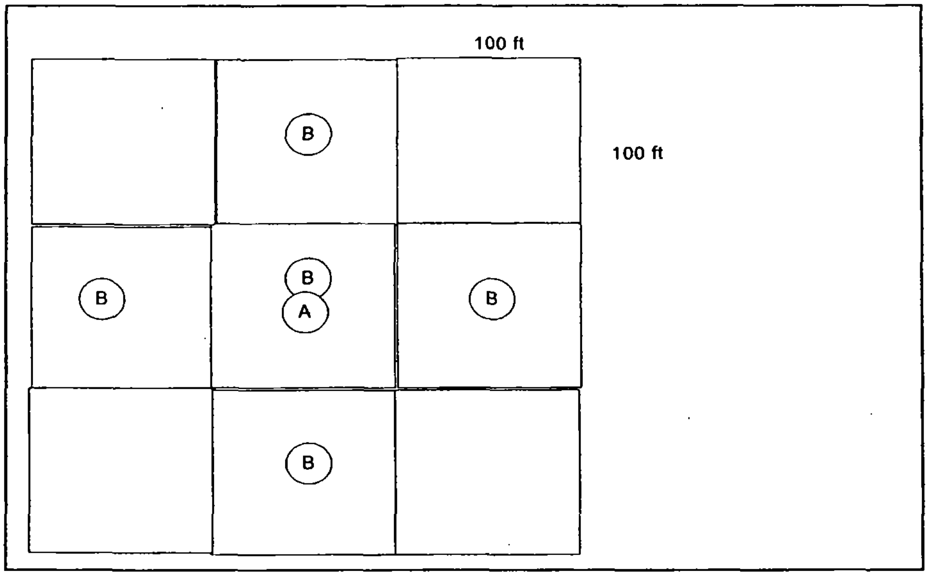
The size of the site is 55 acres (USEPA 2003). Core and grab sampling will initially take place in 34 sampling units of approximately 2 acres each. The sampling units generally are comprised of nine 100- by 100-foot grids. The sampling grid plan is shown in Figure 1 and sampling units are shown in Figure 5. It is planned to initially collect samples in the center of each sampling unit, shown by bullets in Figure 5. These bullets will be adjusted as necessary at the time of sampling to ensure that samples are collected within the site boundaries defined in the ROD. Figure 5 also describes sampling unit and grid nomenclature. Generally, the units and grids described above will be used to locate grab samples on the cap in each of the sampling units (Figure 5).

For the Longfellow Creek area, a more focused scheme, based on three samples within adjacent 100- by 100-foot grids and a designated reference site that is part of the standard sampling series, is adopted. This scheme entails sampling in one subgrid immediately beyond the outfall in RA3 and two grids nearest the outfall in RA2a. (These sampling locations are indicated in the footnote to Figure 5.) Sampling locations in RA2a are being used since collection of samples in RA3 nearest the outfall may not be possible because of the top gravel layer of the RA3 cap. This sampling will determine any trends in the vicinity of the outfall that might affect the cap's surface chemistry. The designated locations may not have sufficient fines content for chemical analysis. In this case, the locations will be field-determined by moving radially outward from the outfall until a suitable substrate is recovered in the sampler.

Decision rules for MO2a are shown in Tables 1, 4, and 5. These apply both to standard and expanded regimes (adjacent grid testing and expanded same-grid retesting; see next section). Chemical testing will indicate locations where concentrations are above SQS chemical criteria. Biological testing may be performed should the contaminant concentration fall between SQS and CSL. Above CSL, biological testing will not be performed. The interpretation of how many exceedances represent a remedy failure is derived from Ecology (1993), which states that a set of three local observations above the criterion should be considered a "cluster of concern. " Hence, should three or more adjacent samples fall between SQS and CSL, or if *any* single sample is above the CSL, the sampling unit will be considered to be recontaminated. Should a cluster of concern occur, expanded or contingent chemical monitoring will be considered. **Note:** For determinations of percent exceedance, *no* stations outside of the cap boundary lines may be used.

6.2.2 Expanded Sediment Testing (MO2a)

Expanded testing will occur on the grid scheme described below should a chemical/biological failure occur or should a substantial area show a significant cap thickness change. If a cap deficiency is observed in the sampled grid in a sampling unit, that grid and adjacent grids will be resampled in the next event (or sooner, if warranted) to determine whether this is a generalized or localized phenomenon. A scheme is presented in the following illustration showing the sampling point in the initial grid (A) and the subsequent five grab samples (B). Best professional judgment may be used to determine whether to resample the center (as illustrated) or to sample an adjacent grid in the sampling unit.



Typical Sampling Unit Layout and Resampling Scheme

Note that not all monitoring grids are nine blocks arranged as a square; some are rectilinear to accommodate site outlines (Figure 5).

This expanded testing will require remobilization of a field crew and a supplemental Field Sampling Plan. A management decision will be made regarding the scope of the expanded testing program. The scope may include collection of one or more of the following:

- Surface grab samples for chemistry only
- Surface grab samples for chemistry and biological testing
- Core samples to support contingent testing described in Section 6.2.4

Should expanded testing confirm a recontaminated portion of the cap, it may be necessary to determine the reason for the condition. This will be done by contingent source investigation sediment testing, described in Section 6.2.4.

6.2.3 Rationale for Number of Sampling Units

The following paragraphs describe a statistical rationale for the 34 sampling units. With the additional three grids for Longfellow Creek, a total of 37 samples will be taken during the first round of chemical sampling. Not all samples will initially be chemically characterized: 23 of the 37 samples will be analyzed. This number includes the Longfellow Creek samples and 20 samples randomly drawn from the rest of the sampling units. The statistical assumptions leading to the rationale for the number of samples will be checked and the number of samples recalculated according to the scheme described below. A determination will then be made on the need for further analysis based upon the results, and more samples may be analyzed as needed and as agreed upon by EPA and/or the State of Washington.

The selection of the number of sampling units for cores or grabs of the entire site is described in the two-part Table 6. In this table, it is assumed that the as-built chemical condition of the cap will resemble that of the Snohomish River material used at another site in 1992 (Table 6a). The more variable of the summed PAH— high-molecular-weight PAH (HPAH)— has a relative standard deviation (RSD) of 0.63.[6] This number was used to calculate the number of sampling locations for the site. Mercury was not used for this calculation because although it had a higher RSD, it was limited in extent at the site. Table 6b shows the calculated number of sampling units, derived using a statistical program titled Visual Sampling Plan (Pulsipher et al. 2002). Using the RSD for HPAH, a Type I error rate of 0.05, a Type II error rate of 0.2, and a minimum detectable difference (also known as a "gray zone") of 0.3 or 30 percent of the threshold value, 34 samples are required to accurately represent the area chemically.[7] The total area of the capped site, 55 acres, divided by 34 yields 1.62 acres, or approximately 2 acres per sampling unit.

The 34 sampling locations are possibly conservative because variability in dredged material chemistry may be greater than that for upland borrow sources. Much of the cap material derives from more homogeneous upland borrow sites. Therefore, although 34 samples from the cap will be collected, only 20 will be analyzed initially. The remaining samples will be archived. The RSD will be evaluated using the Visual Sampling Plan to determine the site-specific required number of samples. The additional number of samples (if any) necessary to adequately represent the site chemically will then be analyzed.

It is also necessary to specify the tolerable uncertainty for sampling error and analytical error. Sampling error will be managed by careful documentation of locations and procedures for sampling. Analytical error will be managed by (1) ensuring that the quantitation limits of the methods are no more than 50 percent of the SQS decision threshold (a) measurement quality objective, or MQO) and (2) by defining DQIs to ensure that the analytical laboratory's method was within control limits during analysis of the samples.

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[6] Relative percent difference (RPD) is calculated as the difference between the readings over the average reading.

[7] The purpose of specifying these assumptions is to ensure that tolerable limits on decision errors have been defined. Subjective assignments have been made for Type I and II errors and minimum detectable difference. The Type I and II error specifications follow EPA standard practice. A retrospective analysis of cleanup decisions in Puget Sound suggests that a 30 to 40 percent minimum detectable difference is being used. This iterative process, a part of the DQO development, significantly influences the tolerable decision error, and it is addressed in more detail in USEPA (2001).

6.2.4 Contingent Source Investigation Sediment Testing (MO2a Contingent)

Figure 4 shows the decision logic involved in testing intended to determine the mode of cap failure. The logic involves analyzing and comparing the surface, mid-cap, and/or bottom-cap chemical concentrations. Frozen archived cores or newly acquired cores will be used for this evaluation. If the majority of cores show increasing concentrations in the direction of the surface, top-down contamination from off-site sources should be considered. Conversely, if the majority of the cores show increasing concentrations away from the surface and there is no indication of significant mass movement of the cap, possible bottom-up recontamination should be considered. For the locations where it appears that bottom-up contamination is occurring, the locations may be compared against the RI data to determine if the failures are occurring at locations where high contaminant concentrations were found in the RI sampling. In either top-down or bottom-up contamination, a management decision would be necessary and could include further investigation, data analysis, and/or recapping.

6.2.5 Incidental Capping of Areas Outside the Remedial Boundaries (MO2b)

The objective of off-site chemical sampling is to determine whether the incidental capping has resulted in surface concentrations below the SQS. Only chemical sampling (no biological sampling) will take place. Upon completion of the RA5 cap, seven surface grab samples in grids approximately 300 feet outside the site boundary will be collected and analyzed to determine the sediment chemistry outside the design cap area. The distance from the site boundary may be changed at the time of sampling depending on the lateral spread of incidental off-cap material as determined by SVPS at the end of the first RA5 construction season. The present proposed locations are shown on Figure 5. There is no associated performance standard, but this monitoring will demonstrate whether incidental capping succeeded in reducing values of PAH to below SQS levels.

As shown in Table 3, only one sampling event is planned in support of this monitoring objective.

6.3 CONSTRUCTION MONITORING, RA5—MONITORING OBJECTIVES 3A, 3B, 3C

6.3.1 Cap Thickness Monitoring in RA5 (MO3a)

Figure 2 contains the decision logic for the construction monitoring to achieve MO3a: *Determine cap thickness during construction in RA5*. Dredged material will be placed at the target locations indicated in the RD (USEPA 2003), and monitoring will be performed at the end of the season to determine the thickness of the cap. The area that meets the RA5 cap depth criterion will be considered complete and added to the long-term monitoring event schedule. For the areas of RA5 that do not meet the depth criteria, more dredged material will be placed and another construction monitoring event will be performed in a subsequent year.

This decision rule (Table 5) uses a minimum 24 inches of cap thickness (after consolidation) in RA5, as specified in the RD. However, there is a second decision that might be made. The RD estimated 13 inches of operational allowance would be needed to ensure a minimum 24-inch cap thickness. If the variation in cap thickness is demonstrated to be less than 13 inches, then the volume for each remaining unit area of RA5 may be reduced somewhat, resulting in a more rapid completion of the cap.

For construction-related cap thickness monitoring in RA5, coring will be used in a manner similar to that shown in the illustration in Section 6.2.2. However, fewer cores may be taken based upon the observations of cores as they are logged. These observations will be the basis for field decisionmaking during the construction work (core data will be evaluated by the Monitoring Task Manager and Support Team ([Figure 7]).

Based on the anticipated availability of suitable dredged material, the RD estimated that two construction seasons will be required to complete RA5. Cores will be collected at the end of each construction season in areas considered complete, at a rate of approximately 2 per acre. For the first construction season, SVPS will be performed from the off-target area toward the target area to determine how far the 8-inch (20-cm) capped area extends outside the target. Cores will be taken once the capped area is expected to exceed 8 inches according to the application rates in the RD. Core information will be used to establish cap thickness to dredge volume ratios for future predictions of cap thicknesses. SVPS will be used to determine the lateral extent of the deposited dredge material.

6.3.2 Monitoring of In-Place TOC for RA5 (MO3c)

The modeling during RD to establish a cap thickness assumed that the in-place cap TOC would be roughly 1 percent. This modeling was then used to specify a cap thickness that will prevent permeation/advection of organic contaminants to the surface and biologically active zone. Four surface samples will be taken of the cap surface after the first construction season and analyzed for TOC. This is to determine whether the as-built cap contains the concentration of TOC that was assumed in the design. If the TOC is $\geq$0.5 percent, no further sampling will be performed. If the TOC is <0.5 percent, the EDC Team will be consulted to evaluate the need for possible corrective actions as described in the CQAP.

6.3.3 Water Quality Monitoring in RA5 (MO3b)

Potential construction-related water quality impacts could occur from cap placement due to water quality criteria exceedances or increased turbidity (reduced transparency of water due to increased suspended solids). The Clean Water Act (CWA) requires a factual determination of potential short- and long-term effects of discharges of proposed dredged or fill material on physical, chemical, and biological components of the aquatic environment. The CWA permits exclusion of materials that are sand, gravel, or other inert materials (40 CFR 230.60[a]). However, dredged sediment proposed for capping will be tested as prescribed in the PSR CMP (USEPA 2004a) to ensure that dredged materials meet acceptable levels of COCs. Water quality impacts from cap placement will be limited to a short-term increase in turbidity in the area of construction. During RD, cap material placement options were reviewed and selected to minimize turbidity during release and to minimize resuspension of existing contaminated bottom sediments. Dredged materials used in RA5 will likely segregate into grain size fractions during each placement event, with the coarser materials falling faster than the finer grain sizes. Some fine-grained materials may remain in suspension for a short time and be carried by currents away from the scow.

At this writing, EPA has not issued a Water Quality Certification, as it does for aquatic Superfund sites. It is assumed here that the same conditions will be used for water quality measurement in RA5 as in RAs 1–4 (USEPA 2003):

- Specification of a 300-foot-radius mixing zone from the scow. The downcurrent edge of the zone is the compliance boundary. The location of the dredging operation and the location of the sampling point are reported along with the observations.

- Two sampling points on the downcurrent compliance boundary and one point, an "early warning" location, at the midpoint of the mixing zone.

- Water quality parameters averaged over the depth of the water column, based on discrete measurements at three water depths. At each sampling station, three depth-specific measurements will be collected at shallow-, intermediate-, and deep-water levels. The shallow measurements will be collected approximately 2 feet below the water surface. The deep measurements will be collected within 6 feet of the mud line, and the intermediate measurements will be collected near the midpoint of the water column.

- An initial startup period of more intense monitoring until the operation is deemed in compliance, and then less intense monitoring.

- Unacceptable water quality impacts. Elliot Bay is designated by the State of Washington as a Class A water body. WAC 173-201-030(2) sets forth the following water quality standards that must be met in Class A waters:

- Dissolved oxygen of less than 6.0 mg/L, or 0.2 mg/L below background if background is less than 6.0 mg/L at the compliance boundary; no dissolved oxygen levels below 4 mg/L at the location midpoint in the mixing zone.

- At the compliance boundary, turbidity of greater than 5 NTU over background if background is less than 50 NTU, or greater than 10 percent over background if background is greater than 50 NTU.

- At the compliance boundary, temperature <16°C, and no incremental increase >0.3°C allowed when background temperature exceeds 16°C.

- Fish or wildlife observed to be distressed or killed.

Frequencies and duration of water quality monitoring will be specified in the EPA/State Water Quality Certification. It is anticipated that water quality monitoring will occur twice weekly over the first 2 weeks; if no water quality exceedances have been demonstrated, monitoring will be suspended or greatly reduced in frequency. Should an exceedance occur, and be confirmed by subsequent monitoring, the oversight personnel and the EDC Team, which oversees the environmental support contractor, will recommend to EPA and the Contracting Officer (CO) whether to discontinue cap placement activities and divert the material to a DMMP site or to modify placement until water quality returns to acceptable levels.

Figures

7.0 REPORTING

A Field Report and a Monitoring Report will be prepared for each year during which monitoring is conducted.

7.1 FIELD SAMPLING REPORT

A Field Sampling Report will be submitted by the contractor to the Monitoring Task Manager for review after each year's monitoring cruise. This report will be reviewed by the Monitoring Task Manager, the EPA Remedial Program Manager, and other interested agencies, as determined by the EPA. The contractor will revise the Field Report to incorporate comments from this review. The Field Report will describe actual field logistics and schedule, procedures and methods, sampling locations, and deviations from the Sampling and Analysis Plan (SAP). It will include the field log, notes, and sampling logs. The Field Report will include the following sections:

- Cruise Objectives
- Chronology of Field Operations
- Field Sampling Methods
- Deviations from the Field Sampling Plan (FSP)
- Summary of Data Collected
- Schedule of Analyses and Reporting
- Appendices
  - Sampling Coordinates
  - Field Log Notes
  - Sample Logs
  - Station Logs

7.2 MONITORING REPORT

Each Monitoring Report will address monitoring conducted during the year of the report. The Monitoring Report will be submitted by the contractor to the Monitoring Task Manager after receipt of validated analytical results. This report will be reviewed by the Monitoring Task Manager, the Remedial Program Manager (EPA), and other interested agencies. The contractor will revise the Monitoring Report to incorporate the comments from this review. The Monitoring Report will describe the site, monitoring objectives, and field, laboratory, and data analysis methods; present analytical results in organized data tables and figures (as appropriate); describe trends if any are apparent; present conclusions about environmental conditions in the MSU as determined by monitoring; and make appropriate recommendations for revisions to the monitoring program if needed. The Monitoring Report will include the following sections:

- Site Description and Background
- Monitoring Objectives
- Methods and Results (for each monitoring type)
  - Sampling Locations and Methods
  - Analytical Methods
  - QA/QC Summary
  - Results
- Summary of Conditions in the MSU
- Comparison of Results to Expectations
- Recommended Revisions to Monitoring
- References
- Appendices

8.0 PROJECT TEAM AND RESPONSIBILITIES

The remedial action in the PSR MSU is authorized and funded by EPA and the State of Washington and is being implemented by the USACE. The long-term monitoring program is a cooperative effort between EPA, the State of Washington, and the USACE as EPA's agent, with either the USACE or contractors conducting the monitoring. Figure 7 shows the team and organization for the long-term monitoring program; the roles of the team members are summarized below. A more detailed project organization identifying individuals responsible for each aspect of the physical, chemical, and biological monitoring is presented in the SAPs for the individual events.

Remedial Program Manager (RPM) (EPA). The EPA RPM is Sally Thomas. As manager of the Puget Sound Resources Marine Sediments Unit Superfund site, EPA has responsibility for the monitoring program. Working with the EPA and USACE scientists, the RPM defines the monitoring objectives; approves monitoring methods, schedule, and monitoring reports; and (with other agency input—not shown in Figure 7) makes decisions regarding modifications to the monitoring program, and determines management action. An EPA technical team (not shown) also provides technical input into monitoring program design and may review field and laboratory operations, data interpretation, and reporting.

Project Manager (PM) (USACE). The PM is Miriam Gilmer, who is team leader for the USACE team. The PM is responsible for ensuring quality of work of this team to EPA, preparing and tracking budgets and schedules, and coordinating tasks.

Technical Support Team (USACE, EPA). This multi-agency group provides technical scoping and contracting support, technical review of monitoring plans and reports, and input on the significance of monitoring results and modifications to the monitoring program.

Contracting Officer (CO) (USACE). The CO for the USACE pre-placed environmental contracts is Ron Bush. The CO has responsibility for contract management and administration; he may designate a Monitoring Task Manager to accomplish tasks to this end. The CO deals with USACE contractors on contractual matter, ensuring that the contractor complies with contract requirements and providing all necessary quality assurance information.

Monitoring Task Manager (MTM) (USACE). The Monitoring Task Manager (also known as the Contracting Officer's Technical Representative) is responsible for directly supervising the contractors and agencies that will conduct the actual field, laboratory, analysis, and reporting tasks for the monitoring. The Monitoring Task Manager will direct the monitoring contractor on a day-to-day basis and provide primary review of all reports and other work products. The Monitoring Task Manager will also coordinate with the Washington State Department of Transportation to ensure that monitoring operations do not interfere with ferry traffic. The MTM will also coordinate activities with the USCG, Crowley Marine, the Tribal Fishing Families, and the Port Police. The USACE MTM is Travis Shaw.

Contractors. The USACE navigation dredging contractor for RA5 is responsible for providing material of predetermined quality to the site and placing it in the manner indicated in the contract specifications, which will be based upon the PSR Construction Quality Assurance Plan for RA5 (USACE 2004b). Dredging contractors hired by other, permitted users of the PSR site will have similar requirements as part of their permit. These contractors must also monitor for water quality parameters. The USACE monitoring contractor (or USACE surveyors) for MO2 will be responsible for implementing all other monitoring investigations, including field sampling, laboratory analysis, data analysis, and reporting. However, if determined by EPA that the EPA Region 10 Manchester Laboratory should be used for analysis or data evaluation, then these responsibilities will be EPA's.

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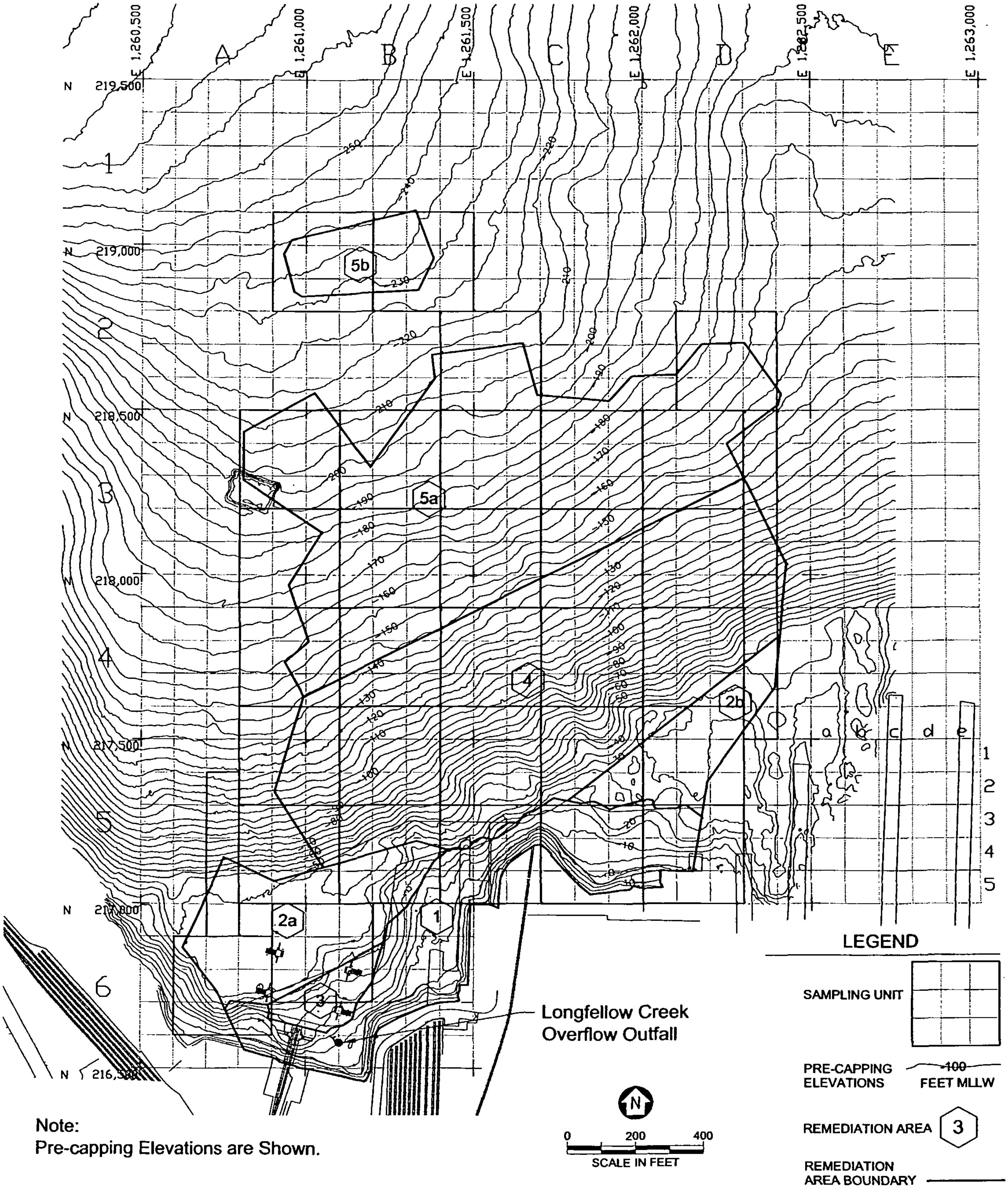

Note:
Pre-capping Elevations are Shown.

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Figure 1
PSR MSU SITE MAP

EPA REGION 10

114-RD-RD-101L
PSR SUPERFUND SITE

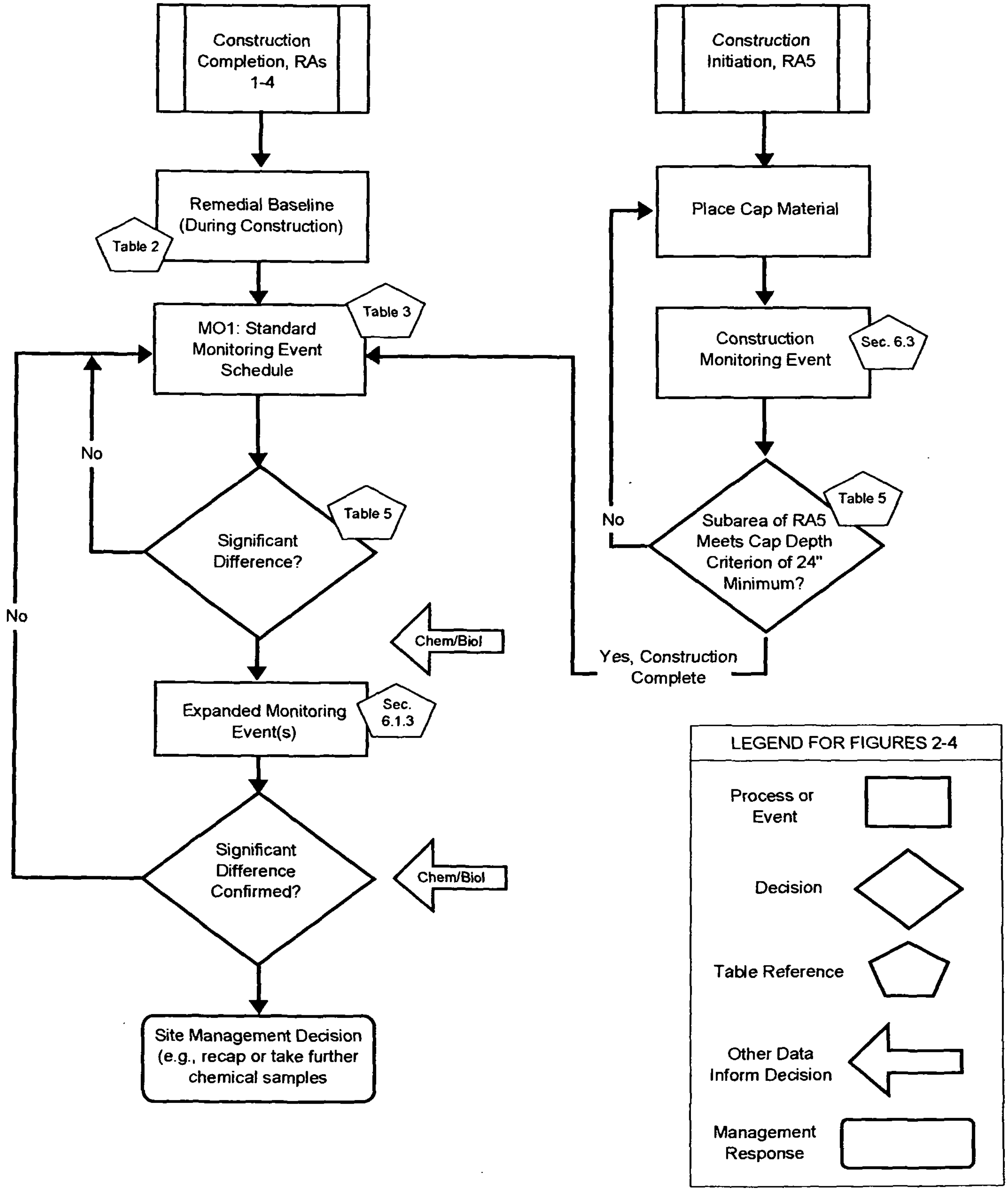


Figure 2
PSR Physical Measures Decision Process

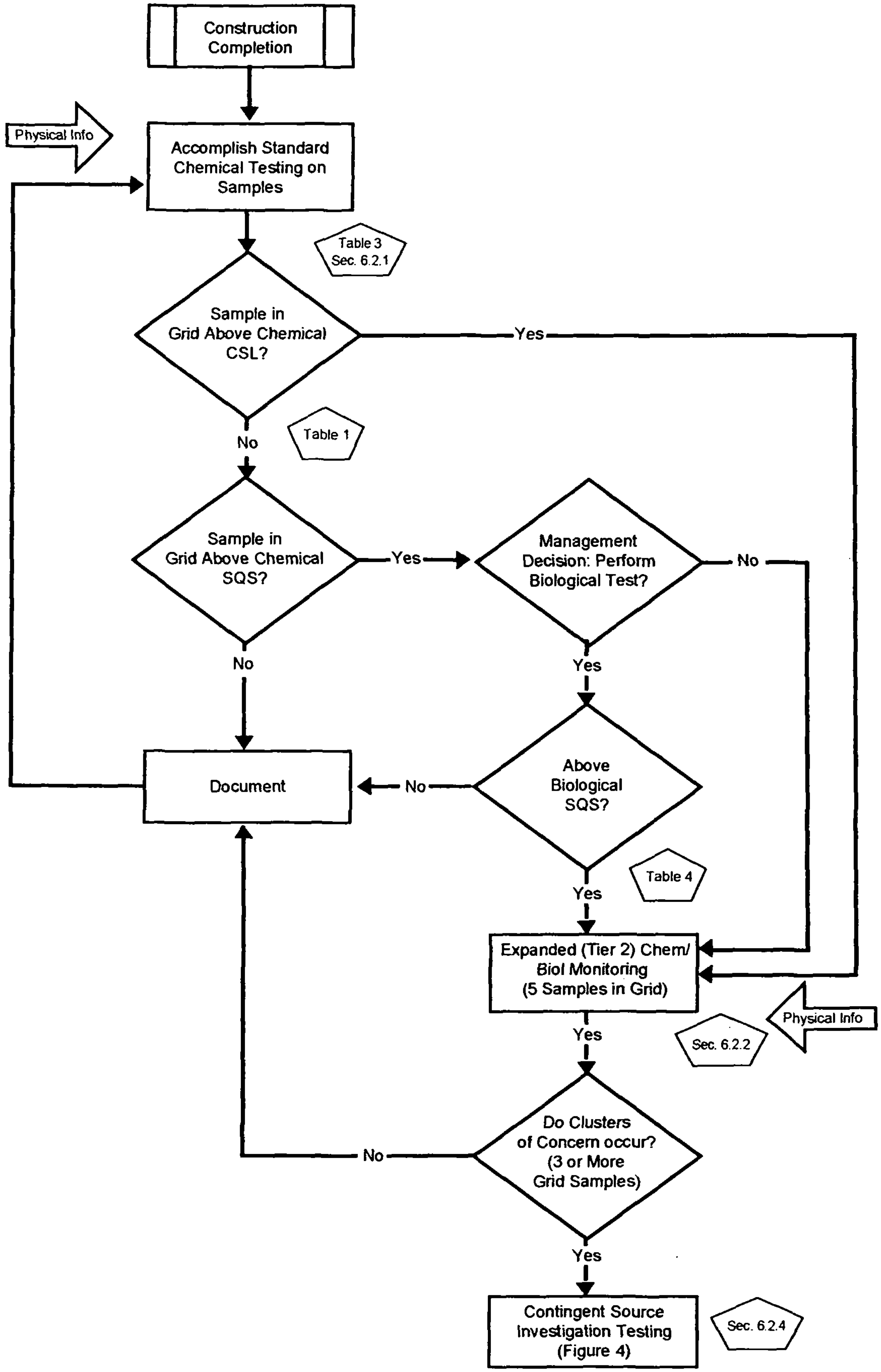


Figure 3

Job No. 33755785

PSR Chemical/Biological Compliance Decision Process

EPA REGION 10

114-RD-RD-101L
PSR Superfund Site

33755785-99a

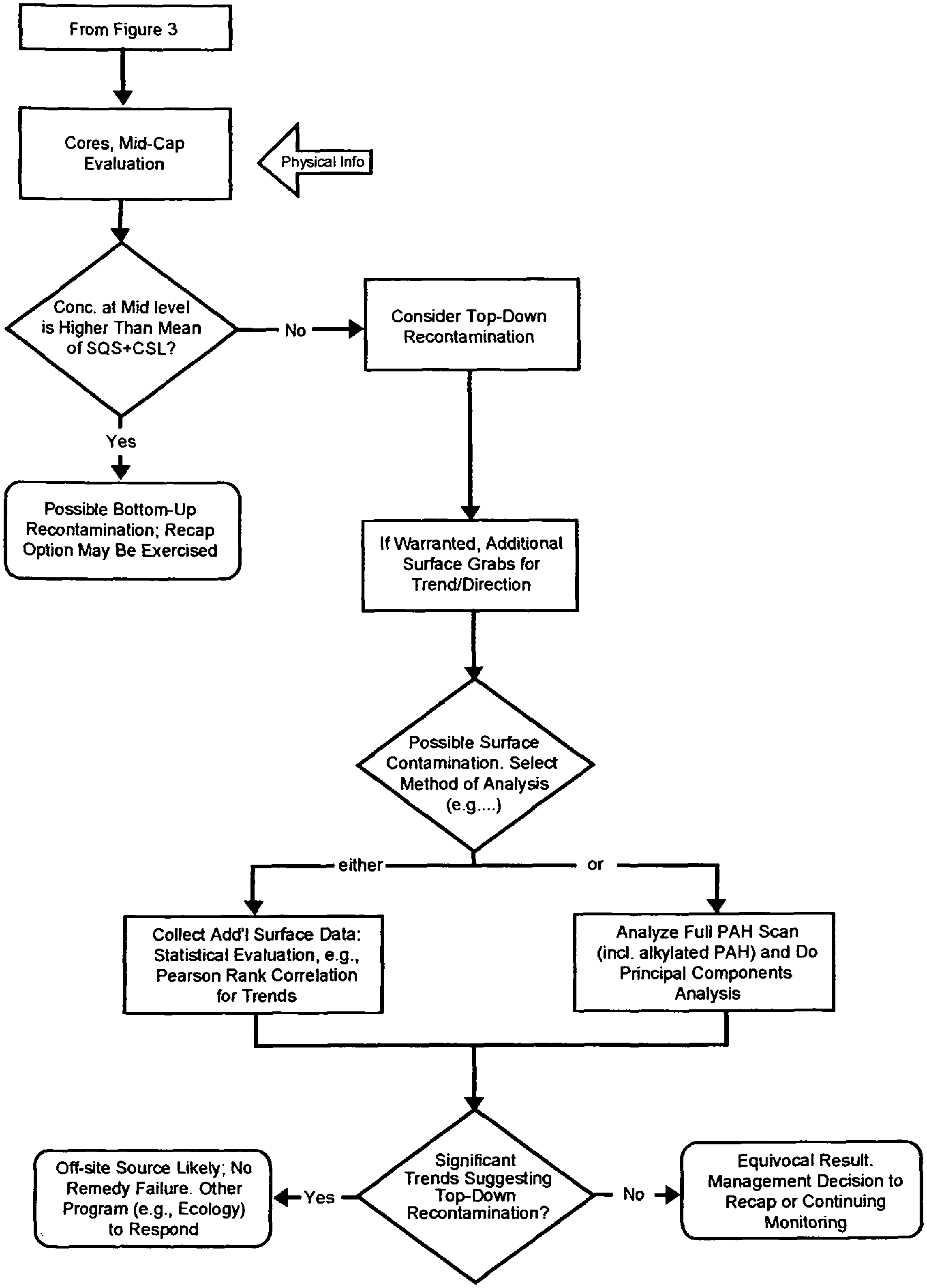
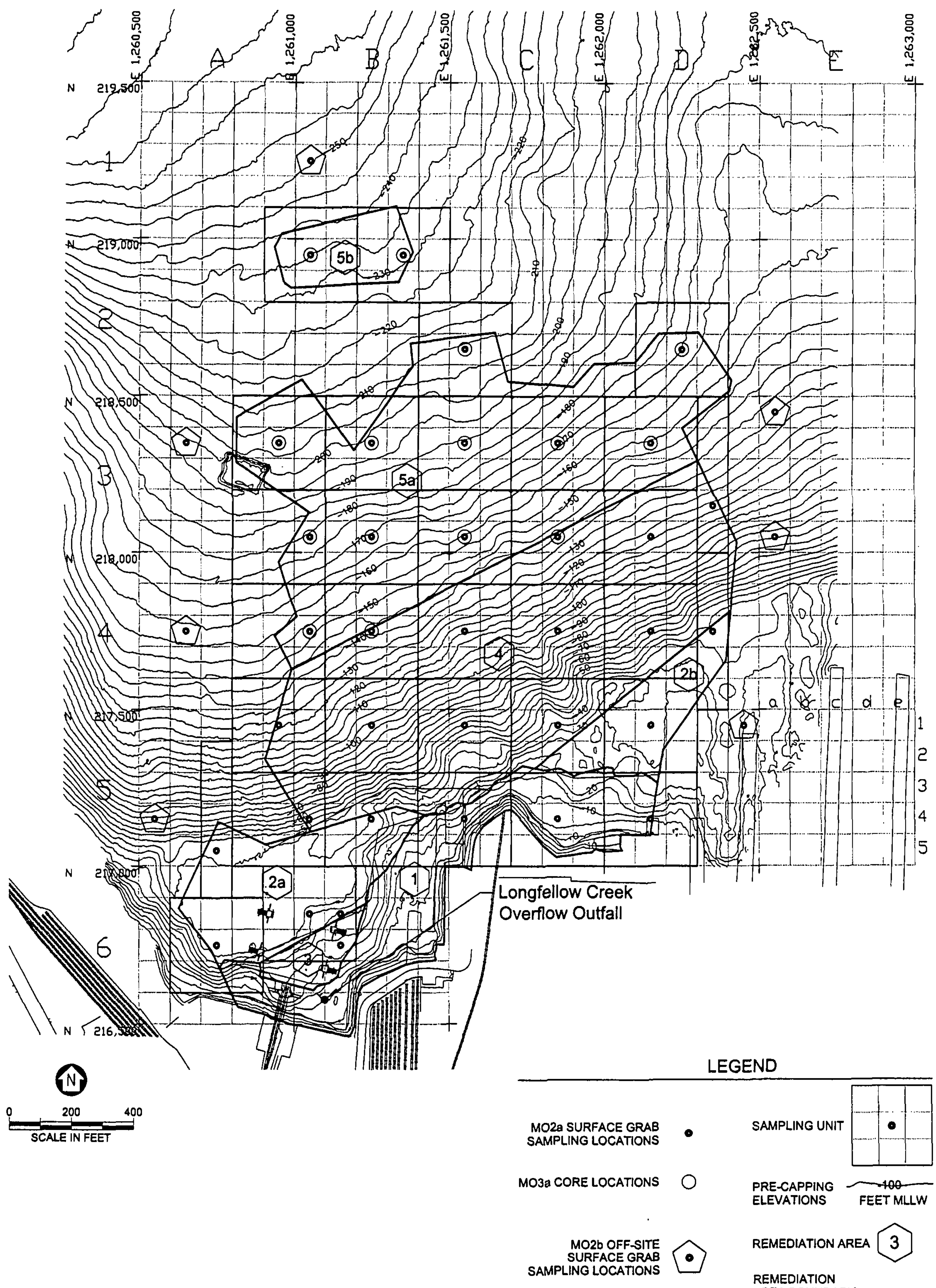


Figure 4
Contingent Source Investigation Testing



Note:
The alphanumeric grid at top and left and the one at lower right provide a means of designating a sampling unit. State Plane Coordinates are shown at right and top, and define a 500x500-foot major grid grouping; these may be referenced as A1-A6, B1-5, etc. Within a 500x500-foot major grid grouping are 25 grids of 100x100 feet each. The lower right grid shows the numbering of these. Thus, it is possible to reference a location and a sampling unit: the left-hand RA5a sampling unit is centered on grid column B, row 2, subcolumn a, row 1, or B2a1. For special sampling at Longfellow Creek, sampling location A6c3 is the reference area for determining trends or differences. Off-site sampling locations are approximate, and will likely be moved farther off-cap. The off-site locations will be selected by reference to SVPS results.

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Figure 5
PSR SAMPLING UNITS AND REFERENCE SYSTEM

EPA
REGION 10

114-RD-RD-101L
PSR SUPERFUND SITE

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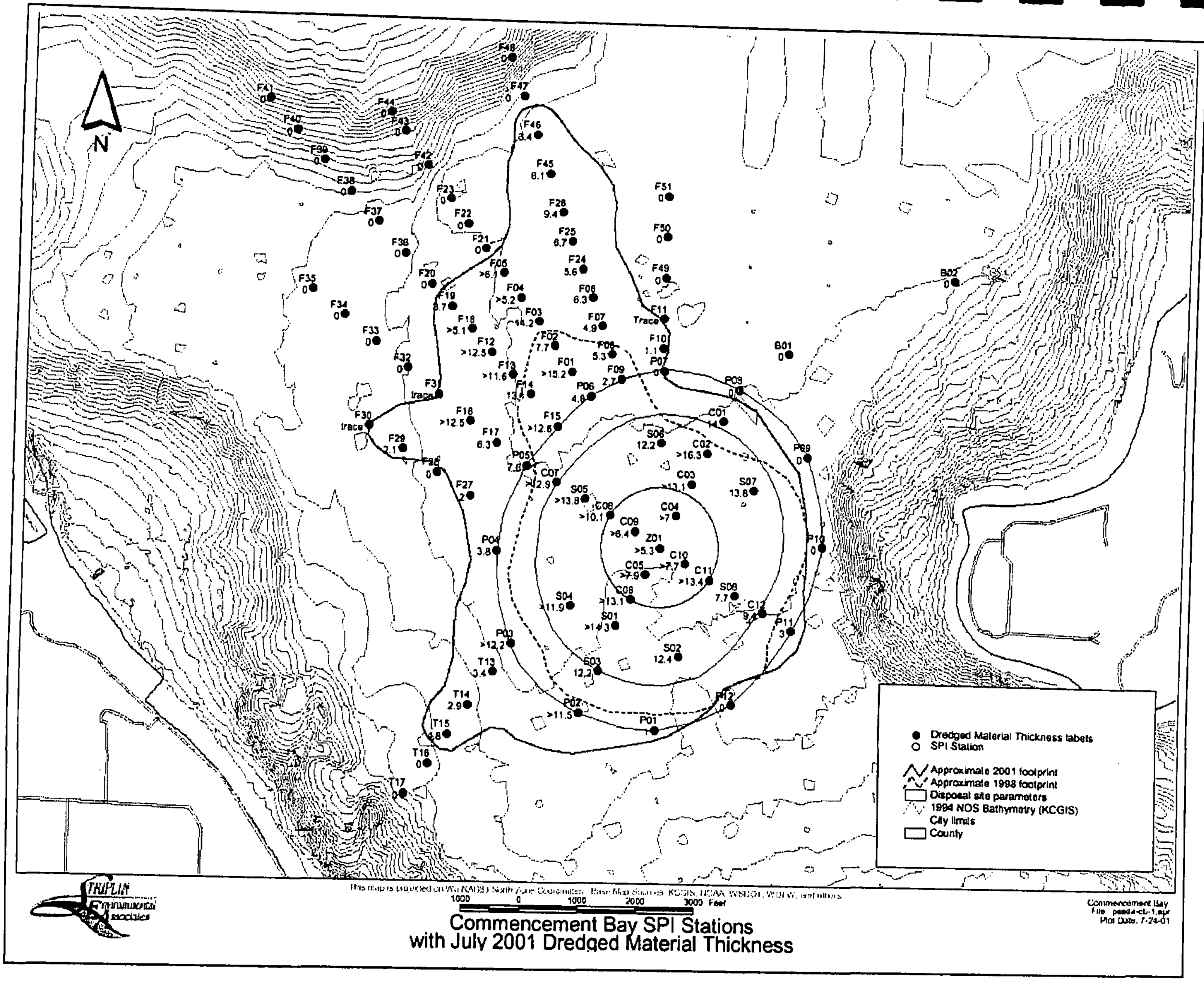

Job No. 33755785

Figure 6

Typical SVPS Survey Approach From Commencement Bay DMMP Site

EPA
REGION 10

114-RD-RD-101L
PSR Superfund Site

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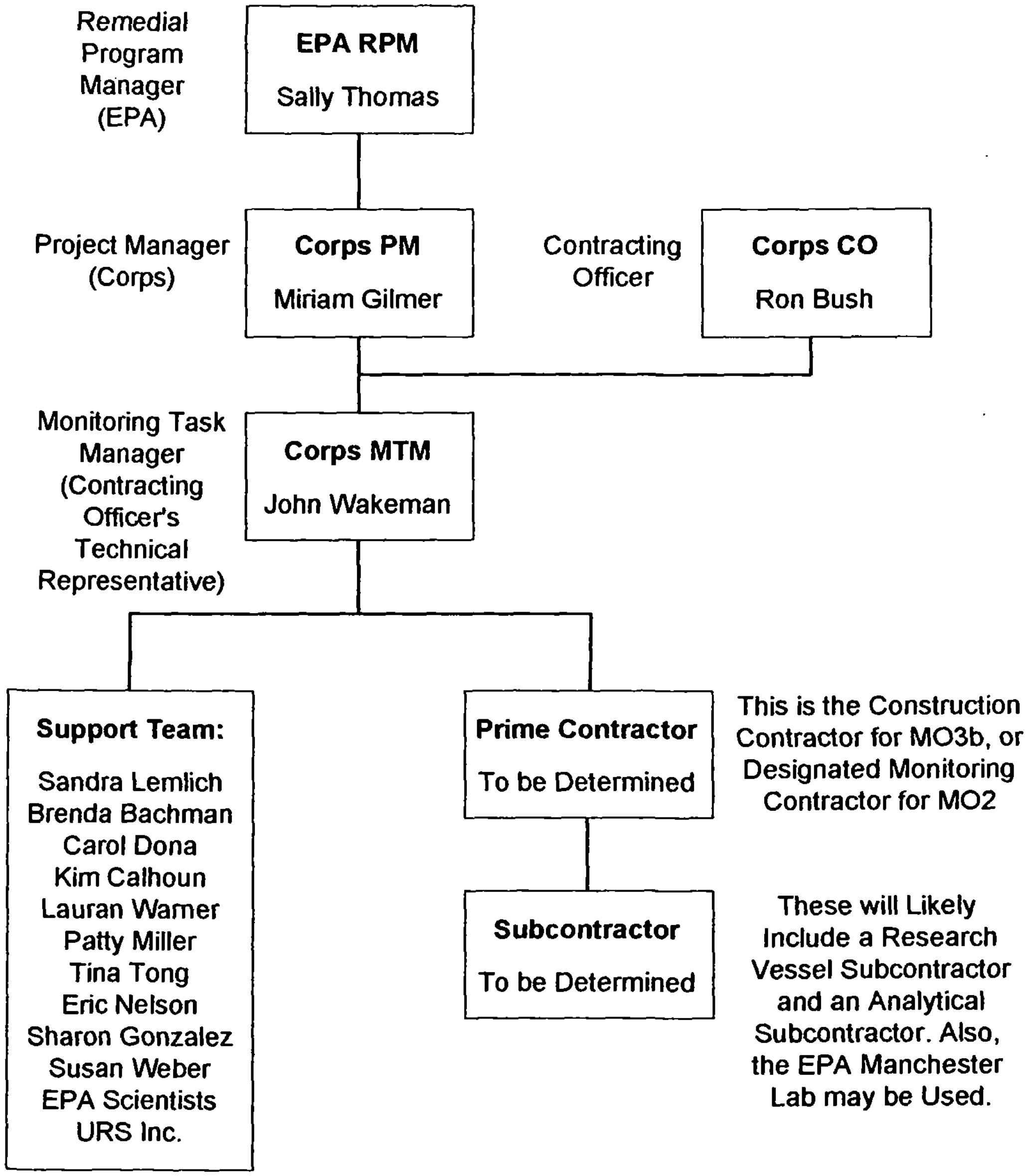

Job No. 33755785

Figure 7
Organization Chart

114-RD-RD-101L
PSR Superfund Site

EPA
REGION 10

Tables

Table 1
Washington State Sediment Management Standards (SMS) Chemical Guidelines

Chemical or Chemical Group	Required for Cap Confirmation?	SQS (mg/kg dry weight)	CSL	Lowest Apparent Effects Threshold[a] (mg/kg dry weight)
Metals				
Arsenic	No	57	93	57
Cadmium	No	5.1	6.7	5.1
Chromium	No	260	270	260
Copper	**Yes**	390	390	390
Lead	No	450	530	450
Mercury	**Yes**	0.41	0.59	0.41
Silver	No	6.1	6.1	
Zinc	**Yes**	410	960	410
		(mg/kg organic carbon normalized)		**(mg/kg dry weight)**
Organic Compounds				
Total LPAH	**Yes**	370	780	5.2
Naphthalene	**Yes**	99	170	2.1
Acenaphthylene	**Yes**	66	66	1.3
Acenaphthene	**Yes**	16	57	0.5
Fluorene	**Yes**	23	79	0.54
Phenanthrene	**Yes**	100	480	1.5
Anthracene	**Yes**	220	1,200	0.96
2-Methylnaphthalene	**Yes**	38	64	0.87
Total HPAH	**Yes**	960	5,300	12
Fluoranthene	**Yes**	160	1,200	1.7
Pyrene	**Yes**	1,000	1,400	2.6
Benz(a)anthracene	**Yes**	110	270	1.3
Chrysene	**Yes**	110	460	1.4
Total benzofluoranthenes	**Yes**	230	450	3.2
Benzo(a)pyrene	**Yes**	99	210	1.6
Indeno(1,2,3,-c,d)pyrene	**Yes**	34	88	0.6
Dibenzo(a,h)anthracene	**Yes**	12	33	0.23
Benzo(g,h,i)perylene	**Yes**	31	78	0.67
1,2-Dichlorobenzene	No	2.3	2.3	
1,4-Dichlorobenzene	No	3.1	9	
1,2,4-Trichlorobenzene	No	0.81	1.8	

Table 1 (Continued)
Washington State Sediment Management Standards (SMS) Chemical Guidelines

Chemical or Chemical Group	Required for Cap Confirmation?	SQS (mg/kg organic carbon normalized)	CSL (mg/kg organic carbon normalized)	Lowest Apparent Effects Threshold[a] (mg/kg dry weight)
Organic Compounds (Continued)				
Hexachlorobenzene	No	0.38	2.3	
Dimethylphthalate	No	53	53	
Diethylphthalate	No	61	110	
Di-n-butylphthalate	No	220	1700	
Butylbenzylphthalate	No	4.9	64	
Bis(2-ethylhexyl)phthalate	No	47	78	
Di-n-octylphthalate	No	58	4500	
Dibenzofuran	**Yes**	15	58	0.54
Hexachlorobutadiene	No	3.9	6.2	
n-Nitrosodiphenylamine	No	11	11	
Total PCBs	**Yes**	12	65	0.13
Phenol	**Yes**	420	1200	0.42
2-Methylphenol	**Yes**	63	63	0.063
4-Methylphenol	**Yes**	670	670	0.67
2,4-Dimethylphenol	**Yes**	29	29	0.029
Pentachlorophenol	**Yes**	360	690	0.36
Benzyl alcohol	No	57	73	
Benzoic acid	No	650	650	
Chlorinated dioxins, furans	Footnote b	Not specified	Not specified	Not specified

[a]Washington State Department of Ecology typically uses dry-weight basis concentrations to determine compliance with SQS outside the range of 0.5–4% total organic carbon.
[b]PCDD/F compounds will not be monitored, as explained in the text.

Table 2
Monitoring Objectives

Overall Objectives	Monitoring Objectives	Rationale
1. Determine whether the capped, dredged site maintains an adequate and effective remedy over the long term.	1. Determine the physical stability of the cap.	1. The physical stability of the cap is important to the cap's ability to isolate the underlying contaminants over the long term and to ensure maintenance of a clean sediment cover, which minimizes the effects of contamination on the benthic community. Physical stability is an indicator of cap functioning as opposed to a strict compliance standard. (See Objective 2.)
	2a. Determine the performance of the surface of the cap relative to State of Washington SQS.	2a. Effects testing (chemical and biological) will ensure that the surface site condition of the cap meets SQS. Contingent testing may be needed to determine the means of recontamination that may occur. For instance, off-site sources of contamination may indicate a differing biological condition not related to the cap's effectiveness.
	2b. Assess the benefits of incidental capping of areas outside the remedial boundaries.	2b. While not intended by the ROD to be addressed by the remedial action, the condition of sediments in the vicinity of PSR but outside of the capped area is of interest. The sediments are initially SQS<x<CLS and will be tested occasionally to determine whether "incidental capping" has occurred. There is no ROD performance standard for these results, however.
2. Provide an effective constructed cap in RA5. (This is verified for the long term in Objective 1.) Also, ensure that placement is environmentally compliant.	3a. Determine the cap thickness resulting from the volumes of dredge material placed in RA5 during construction.	3a. Knowledge of the cap thickness given the volume of dredge material placed during construction will permit refinement of how much material is necessary to complete the designed cap.

Table 2 (Continued)
Monitoring Objectives

Overall Objectives	Monitoring Objectives	Rationale
2. (Continued)	3b. Determine compliance with Water Quality Certification.	3b. Water quality monitoring for suspended solids, turbidity, and dissolved oxygen near the point of discharge of dredged material during capping will determine compliance.
	3c. Determine that in-place cap contains TOC at concentrations consistent with RD assumptions	3c. Significantly lower TOC could require engineering analyses or design modifications.

Table 3
Basic Monitoring Schedule and Objectives Covered Under the OMMP

Remediation Area	Location	Monitoring Objectives (MO) and Proposed Methods	2003–4	2004–5	2005–6	2006–7	2007–8	2008–9	2009–10	2010–11	2011–12	2012–13
Monitoring Year			1	2	3	4	5	6	7	8	9	10
1	Intertidal	MO1: Topographic survey, visual observation, fixed location photographs; beach inspections MO2a: Chemical/biological	in (Note 2)	in (Note 2)	in (Note 2)	in (Note 2)	spc in (Note 2)	in (Note 2)	in (Note 2)	in (Note 2)	in (Note 2)	spc in (Note 2)
1, 2, 3, 4	Subtidal	MO1: Multibeam survey (Note 1) MO2a: Chemical/biological	(Note 1)				spc					spc
Longfellow Creek Relocated Outfall	Subtidal	MO1: Multibeam survey (Note 1) MO2a: Chemical/biological					spc					spc
5 During Construction	Subtidal	MO3a: Cores, SVPS in area around active capping zone MO3b: Water quality monitoring MO3c: TOC in cap during construction		cp, wq, toc (Note 3)	cp, wq (Note 3) (Note 4)							
5 After Construction	Subtidal	MO1: Multibeam survey MO2: Chemical/biological			(Note 6)		spc					spc
Off-Cap Vicinity	Subtidal	MO2b: Chemical					lpc (Note 5)					

Table 3 (Continued)
Basic Monitoring Schedule and Objectives Covered Under the OMMP

Notes:

1. The baseline physical and chemical events will be performed during the construction phase at the completion of each of the RA1–4 caps.
2. Beach inspections will also be performed as necessary following seismic events and major storms.
3. Only the area of RA5 where dredge material was deposited in the current construction season will be monitored.
4. The totality of cp surveys is the baseline physical for RA5. SVPS will also be performed off the cap after cap completion.
5. Not a performance standard for the cap.
6. A multibeam survey will establish baseline bathymetry in RA5 once capping is determined to be complete. This may be deferred until the 2007–2008 spc event.

Legend:

MO1: physical stability indicators
MO2: chemical/biological effects condition compliance
MO3: refinement of construction procedures in RA5
cp - construction-related physical monitoring (cores and SVPS)
sc - standard chemical monitoring only; informal monitoring objective, not compliance related
spc - standard physical/chemical/biological monitoring; MO2
lpc - limited physical (SVPS) and chemical (only) monitoring
wq - water quality
in - beach inspection
toc - surface TOC determination in RA5
Shaded cells: PSR 5-year reviews are scheduled in September 2004 and September 2009.

Table 4
SMS Bioassays, Interpretation, and Data Quality Indicators

Solid Phase Bioassay Performance Standards and Evaluation Guidelines. See also Table 12.

Bioassay	Negative Control Performance Standard	Reference Sediment Performance Standard	SMS Interpretation Guidelines[a]
Amphipod	$M_C \leq 10\%$	$M_R - M_C \leq 25\%$	$M_T - M_C > 20\%$ and M_T vs M_R SD (p=0.05) and
			$M_T - M_R > 10\%$
Larval	$N_C \div I \geq 0.38$	$N_R \div N_C \geq 0.65$	$N_T \div N_C < 0.70$ and N_T/N_C vs N_R/N_C SD (p=0.05) and
			$N_R/N_C - N_T/N_C > 0.15$
Neanthes growth	$M_C \leq 10\%$ and $MIG_C \geq 0.38$	$M_R \leq 20\%$ and $MIG_R \div MIG_C \geq 0.80$	$MIG_T \div MIG_C < 0.80$ and MIG_T vs MIG_R SD (p=0.05) and
			$MIG_T/MIG_R < 0.70$

[a]The SMS have not been modified since the 1996 Annual Review Meeting clarified the growth acceptance value of 0.38 mg/individual/day. In the outdated but not repromulgated SMS, the value given is still 0.72 mg/individual/day. The DMMP update will be used as it is standard practice for the SMS program as well as the DMMP. Reference: <http://www.nws.usace.army.mil/publicmenu/DOCUMENTS/neant_96.pdf>

M - mortality, N - normals, I - initial count, MIG - mean individual growth rate (mg/individual/day)
SD - statistically different
Subscripts: R - reference sediment, C - negative control, T - test sediment

Table 5
Decision Rules

Remediation Area	Location	Physical Indicators		SMS Compliance Criteria	
		MO1: Physical Stability	**MO3: Construction Effectiveness Indicators**	**MO2: Chemical**	**MO2: Biological (Note 1)**
1	Intertidal	• Erosion of >3 feet has occurred related to as-built conditions. • Erosion of >1 foot per survey for two successive surveys has occurred. • Visual observations indicate exposure of the chemical isolation layer. • Visual observations indicate significant beach features suggesting instability. • Best professional judgment is needed.	NA	BAZ >SQS chem (Note 6)	BAZ > SQS bio (Note 6)
1, 2, 3, 4, 5	Subtidal	• Erosion of >1 foot is occurring related to as-built conditions over substantial area. (Notes 2, 3)	NA	BAZ >SQS chem (Note 7)	BAZ > SQS bio
Longfellow Creek Relocated Outfall	Subtidal	NA	NA	BAZ >SQS chem	BAZ > SQS bio
5 During Construction	Subtidal	NA	Observed cap is less than designed cap thickness (24 inches).	BAZ >SQS TOC <0.5% (Note 8)	NA
Off-Cap Vicinity	Subtidal	NA	NA	(Note 4)	NA

Table 5 (Continued)
Decision Rules

Remediation Area	Location	Physical Indicators		SMS Compliance Criteria	
		MO1: Physical Stability	MO3: Construction Effectiveness Indicators	MO2: Chemical	MO2: Biological (Note 1)
Water Quality, RA5 During Construction	0 foot MLLW, 50% of distance top to bottom	NA	• (Note 5) Dissolved oxygen: Less than 6 mg/L, or greater than 0.2 mg/L below background if background is <6 mg/L • Turbidity: Greater than 5 NTU over background if background is less than 50 NTU, or greater than 10% over background if background is greater than 50 NTU	NA	NA

NA - not applicable; BAZ - biologically active zone or zone of compliance: 0–10 cm

Notes:
1. Contingent test that may be performed if chemistry is > SQS but < CSL.
2. Seismic events of greater than dry ground surface peak ground acceleration of 0.12 g measured at the Harbor Island seismometer will be the basis for a "special" multibeam survey to ascertain whether mass movements have occurred.
3. "Substantial area" will be based upon professional judgment and may differ according to the measurement being taken. See text.
4. It is believed that off-site sediments with concentrations currently between SQS and CSL will have been incidentally capped below SQS. This is not a performance criterion.

Table 5 (Continued)
Decision Rules

5. These are tentative and will determined in the EPA Water Quality Certification.
6. It may be difficult to effectively test the surfaces in RA1 and RA3 due to coarse grain size (gravel top layers in RA1 and RA3). In these areas, the rules are included should there be an accretion of fine-grained sediments on the top of the cap.
7. As described in the text, "clusters of concern" will be used to determine significance of chemical/biological hits.
8. During-construction chemical compliance is generally ensured through chemical testing of dredged material management units. TOC <0.5 percent will trigger consultation with the EDC Team.

Table 6
Calculation of Number of Grids for SMS Confirmation

a. Anticipated Variability in Sediments After Capping

Chemical or Chemical Group	Snohomish River Volume Weighted Average[a]	Unit	2001 PSR Averages[b]	Unit	Relative Standard Deviation (RSD) for Snohomish River Dredged Sediments[a]
Total OC	1.5	%	5.38	%	
Mercury	0.04	mg/kg	0.435	mg/kg	0.78
Total LPAH	8.1	ug/kg	224,780	ug/kg	0.48
Acenaphthene		ug/kg	41,200	ug/kg	
Acenaphthylene		ug/kg	1,670	ug/kg	
Anthracene		ug/kg	34,400	ug/kg	
Fluorene	26.1	ug/kg	76,700	ug/kg	
Naphthalene	46.4	ug/kg	28,500	ug/kg	
Phenanthrene	80.6	ug/kg	76,600	ug/kg	
Total HPAH	36.5	ug/kg	399,110	ug/kg	0.63
Benzo(a)anthracene	16.1	ug/kg	37,400	ug/kg	
Benzo(a)pyrene	7.7	ug/kg	9,040	ug/kg	
Benzo(g,h,i)perylene	40.5	ug/kg	2,130	ug/kg	
Benzofluoranthenes	60.4	ug/kg	26,830	ug/kg	
Chrysene		ug/kg	39,200	ug/kg	
Dibenzo(a,h)anthracene	81.4	ug/kg	1,360	ug/kg	
Fluoranthene	18.5	ug/kg	175,000	ug/kg	
Indeno(1,2,3-c,d)pyrene	80.5	ug/kg	3,150	ug/kg	
Pyrene	341.6	ug/kg	105,000	ug/kg	

[a]SAIC 1992. (Values used for capping Wyckoff/Eagle Harbor West Operable Unit).
[b]URS 2001. Note that this does not include the area to be dredged.

b. Influence of RSD and Other Uncertainty Aspects on Selection of Number of Sampling Units

Type 1 Error	Type 2 Error	Minimum Detectable Difference	Action Level	Relative Standard Deviation	Samples
0.05	0.1	0.3	1	0.5	26
0.05	0.2	0.3	1	0.5	19
0.05	0.2	0.3	1	0.63	34
0.05	0.1	0.3	1	0.68	40
0.05	0.1	0.3	1	0.8	63

The measurement unit is the entire site (including RA5 once constructed).
Shaded cells indicate parameters used to select the number of sampling units.

Table 7
Overview of Decision Rules, MQOs, and DQIs

Objective	Measurement Method	Decision Rule	Measurement Quality Objective	Data Quality Indicator
MO1	Topography, visual inspection	Significant differences in cap thickness and slope	Horizontal precision of 3 feet, vertical precision of 0.1 foot	Repeated measurement at nearby monument
	Visual inspection, photography	Significant differences in cap appearance	Professional judgment as to site-specific occurrences	Multiple observers of beach
	Multibeam bathymetry	Depths <100 feet MLLW: 1-foot loss over significant area Depths >100 feet MLLW: Apparent mass movements	0.5-foot single-event precision (0.7-foot between-survey precision)	Repeated survey on an area of 100 by 100 feet
	Through-cap cores	Depths >100 feet MLLW: 1-foot loss over significant area (contingency for MO2a)	0.5-foot precision	Repeated coring of same grid (if expanded coring is performed)
MO2a	Surface samples followed by chemical analysis of sediment	If CSL>BAZ>SQS, possible biological testing. If BAZ>CSL, additional chemical testing	PQL < 0.5X SQS. See Table 8.	See Table 9.
	Surface samples followed by biological analysis of sediment or benthic community measure	If BAZ> biological SQS, then possible additional sample collection and analysis	See fourth column in Table 4.	See fifth column in Table 4.
MO2b	Field instrument measurement of water quality parameters	Dissolved oxygen: Less than 6 mg/L, or greater than 0.2 mg/L below background if background is <6 mg/L Turbidity: Greater than 10 NTU over background if background is less than 50 NTU or greater than 10% over background if background is greater than 50 NTU	Precision of 5% above 50 NTU; precision of 3 NTU if turbidity < 50 NTU	Daily calibration of instrumentation
MO3a	Through-cap cores	24 inches	0.5-foot precision	Repeated coring of same grid (if expanded coring is performed)

Table 7 (Continued)
Overview of Decision Rules, MQOs, and DQIs

Objective	Measurement Method	Decision Rule	Measurement Quality Objective	Data Quality Indicator
MO3b	SVPS	Cap thickness <8 inches	Discern cap/old sediment interface.	At least 4-inch penetration of SVPS prism into cap
MO3c	Surface sample collection with TOC analysis	Cap TOC as-built condition should be at or greater than 1%. This condition was established during the Remedial Design as a suitable value to restrict permeation of the cap by soluble contaminants.	Minimum sensitivity 0.5 percent (see Sec. 6.3.2).	See Table 9.

Table 8
Chemical MQOs

Chemical or Chemical Group	SQS (mg/kg dry weight)	Dry Weight Equivalent to SQS	Selection of MQO (Shaded) (0.7*mg/kg dry weight equivalent)		Typical Detection/Quantitation Limits (for PAH, PCB)
Metal					
Arsenic	57		39.9		
Cadmium	5.1		3.57		
Chromium	260		182		
Copper	390		273		
Lead	450		315		
Mercury	0.41		0.287		
Silver	6.1		4.27		
Zinc	410		287		
Chemical or Chemical Group	**(mg/kg organic carbon normalized [OCN])**	**(mg/kg, dry)**	**(0.7*SQS [OCN] at 1% OC [mg/kg dry])**	**(0.7*mg/kg dry weight equivalent)**	**Detection/Reporting Limits, (mg/kg dry) (Bolding Indicates Need for Special Care for That Measure)**
Nonionizable Organic Compounds					
Total LPAH	370	5.2	2.590	3.640	0.2/0.4
Naphthalene	99	2.1	0.693	1.470	0.2/0.4
Acenaphthylene	66	1.3	0.462	0.910	0.2/0.4
Acenaphthene	16	0.5	0.112	0.350	0.2/**0.4**
Fluorene	23	0.54	0.161	0.378	**0.2/0.4**
Phenanthrene	100	1.5	0.700	1.050	0.2/0.4
Anthracene	220	0.96	1.540	0.672	0.2/0.4

Table 8 (Continued)
Chemical MQOs

Chemical or Chemical Group	SQS (mg/kg organic carbon normalized [OCN])	Dry Weight Equivalent to SQS (mg/kg, dry)	Selection of MQO (Shaded)		Detection/Reporting Limits, (mg/kg dry) (Bolding Indicates Need for Special Care for That Measure)
			(0.7*SQS [OCN] at 1% OC [mg/kg dry])	(0.7*mg/kg dry weight equivalent)	
Nonionizable Organic Compounds (Continued)					
2-Methylnaphthalene	38	0.67	0.266	0.469	0.2/**0.4**
Total HPAH	960	12	6.720	8.400	0.2/0.4
Fluoranthene	160	1.7	1.120	1.190	0.2/0.4
Pyrene	1000	2.6	7.000	1.820	0.2/0.4
Benz(a)anthracene	110	1.3	0.770	0.910	0.2/0.4
Chrysene	110	1.4	0.770	0.980	0.2/0.4
Total benzofluoranthenes	230	3.2	1.610	2.240	0.2/0.4
Benzo(a)pyrene	99	1.6	0.693	1.120	0.2/0.4
Indeno(1,2,3,-c,d)pyrene	34	0.6	0.238	0.420	0.2/**0.4**
Dibenzo(a,h)anthracene	12	0.23	0.084	0.161	**0.2/0.4**
Benzo(g,h,i)perylene	31	0.67	0.217	0.469	0.2/0.4
1,2-Dichlorobenzene	2.3	0.035	0.016	0.025	**0.2/0.4**
1,4-Dichlorobenzene	3.1	0.11	0.022	0.077	0.2/**0.4**
1,2,4-Trichlorobenzene	0.81	0.031	0.006	0.022	
Hexachlorobenzene	0.38	0.022	0.003	0.015	
Dimethylphthalate	53	0.071	0.371	0.050	
Diethylphthalate	61	0.2	0.427	0.140	
Di-n-butyphthalate	220	1.4	1.540	0.980	
Butylbenzylphthalate	4.9	0.63	0.034	0.441	

Table 8 (Continued)
Chemical MQOs

Chemical or Chemical Group	SQS (mg/kg organic carbon normalized [OCN])	Dry Weight Equivalent to SQS (mg/kg, dry)	Selection of MQO (Shaded)		Detection/Reporting Limits, (mg/kg dry) (Bolding Indicates Need for Special Care for That Measure)
			(0.7*SQS [OCN] at 1% OC [mg/kg dry])	(0.7*mg/kg dry weight equivalent)	
Nonionizable Organic Compounds (Continued)					
Bis(2-ethylhexyl)phthalate	47	1.3	0.329	0.910	
Di-n-octylphthalate	58	6.2	0.406	4.340	
Dibenzofuran	15	0.54	0.105	0.378	
Hexachlorobutadiene	3.9	0.011	0.027	0.008	
n-Nitrosodiphenylamine	11	0.28	0.077	0.196	
Total PCBs	12	0.13	0.084	0.091	0.02/0.03 (by aroclor)
Ionizable Organic Compounds					
Phenol	420	0.42		0.294	
2-Methylphenol	63	0.063		0.044	
4-Methylphenol	670	0.67		0.469	
2,4-Dimethylphenol	29	0.029		0.020	
Pentachlorophenol	360	0.36		0.252	
Benzyl alcohol	57	0.57		0.399	
Benzoic acid	650	0.65		0.455	

Table 9
Quality Control Procedures for Organic Analyses

Quality Control Procedure	Frequency	Control Limit	Corrective Action
Instrument Quality Assurance/Quality Control			
Initial Calibration	As recommended by PSEP (1996a) and specified in analytical protocol	≤30% RSD for SVOCs and VOCs; ≤20% RSD for PCBs Relative response factor ≤0.05 for SVOCs and VOCs	Laboratory to recalibrate and reanalyze affected samples
Continuing Calibration	After every 10–12 samples (6 samples for PCBs) or every 12 hours (6 hours for PCBs), whichever is more frequent, and after the last sample of each work shift	≤25% RSD for SVOCs and VOCs; ≤15% RSD for PCBs Relative response factor ≤0.05 for SVOCs and VOCs	Laboratory to recalibrate and reanalyze affected samples
Method Quality Assurance/Quality Control			
Holding Times	Not applicable	1 year (samples stored frozen [−18°C]), or 14 days (samples stored at 4°C) for SVOCs and PCBs; analyze extract within 40 days; 14 days (samples stored at 4°C) for VOCs	Qualify data or collect fresh samples
Method Blank	With every extraction batch; every 12-hour shift for VOCs	Analyte concentration >PQL (the limit of detection constitutes the warning limit)	Laboratory to eliminate or greatly reduce contamination; reanalyze affected samples
Surrogate Compounds	Added to every sample as specified in analytical protocol	EPA CLP control limits	Laboratory to follow EPA CLP protocols (reanalyses or reextraction may be required)

Table 9 (Continued)
Quality Control Procedures for Organic Analyses

Quality Control Procedure	Frequency	Control Limit	Corrective Action
Matrix Spike Sample and Matrix Spike Duplicate	With every sample batch or every 20 samples, whichever is more frequent	Recovery of 50–150 percent; precision of ≤50 RPD	Follow EPA CLP protocols
Laboratory Control Sample	With every sample batch or every 20 samples, whichever is more frequent	Recovery of 50–150 percent	Laboratory to correct problem and reanalyze affected samples
Internal Standards	Added to every sample as specified in analytical protocol	Area response of 50–200 percent of calibration standard; retention time within 30 seconds of calibration standard	Laboratory to correct problem and reanalyze affected samples
Detection Limits	Not applicable	See Table 8	Laboratory must initiate corrective actions (which may include additional cleanup steps as well as other measures) and contact the QA/QC Coordinator and/or Project Manager immediately.
Field Quality Assurance/Quality Control			
Field Replicates	At Project Manager's discretion	Not applicable	Not applicable
Blind Certified Reference Material	Overall frequency of 5 percent of field samples	Within 95 percent confidence interval of true value	At Project Manager's discretion: discuss results with laboratory; qualify sample results

Table 9 (Continued)
Quality Control Procedures for Organic Analyses

Notes:
CLP - Contract Laboratory Program (EPA)
EPA - U.S. Environmental Protection Agency
PCB - polychlorinated biphenyl
PQL - protection quantification limit
RPD - relative percent difference
RSD - relative standard deviation
SVOC - semivolatile organic compound
VOC - volatile organic compound

Table 10
Quality Control Procedures for Metal Analyses

Quality Control Procedure	Frequency	Control Limit	Corrective Action
Instrument Quality Assurance/Quality Control			
Initial Calibration	Daily	Correlation coefficient ≥ 0.995	Laboratory to recalibrate the instrument and reanalyze any affected samples
Initial Calibration Verification	Immediately after initial calibration	90–110 percent recovery (80–120 percent for mercury)	Laboratory to resolve discrepancy prior to sample analysis
Continuing Calibration Verification	After every 10 samples or every 2 hours, whichever is more frequent, and after the last sample	90–110 percent recovery (80–120 percent for mercury)	Laboratory to recalibrate and reanalyze affected samples
Initial and Continuing Calibration Blanks	Immediately after initial calibration, then 10 percent of samples or every 2 hours, whichever is more frequent, and after the last sample	Analyte concentration ≥CRDL	Laboratory to recalibrate and reanalyze affected samples
ICP Interelement Interference Check Sample	At the beginning and end of each analytical sequence or twice per 8 hour shift, whichever is more frequent	80–120 percent of the true value	Laboratory to correct problem, recalibrate, and reanalyze affected samples
Method Quality Assurance/Quality Control			
Holding Times	Not applicable	6 months if samples are held at 4°C; 2 years if samples are frozen (–18°C); 28 days for mercury regardless of whether samples are held at 4°C or frozen	Qualify data or collect fresh samples
Method Blanks	With every sample batch or every 20 samples, whichever is more frequent	Analyte concentration ≥CRDL	Laboratory to redigest and reanalyze samples with analyte concentrations <10 times the highest method blank

Table 10 (Continued)
Quality Control Procedures for Metal Analyses

Quality Control Procedure	Frequency	Control Limit	Corrective Action
Laboratory Control Sample	With every sample batch or every 20 samples, whichever is more frequent	EPA control limits (varies with laboratory control sample)	Laboratory to correct problem and redigest and reanalyze affected samples
Matrix Quality Assurance/Quality Control			
Matrix Spike Sample	With every sample batch or every 20 samples, whichever is more frequent	75–125 percent recovery	Laboratory may be able to correct or minimize problem, or to qualify and accept data
Duplicate Sample Analysis	With every sample batch or every 20 samples, whichever is more frequent	±35 RPD (2 times CRDL for sample duplicate results >5 times CRDL)	Laboratory may be able to correct or minimize problem, or to qualify and accept data as reported
Method of Standard Additions (for GFAA)	As required when analytical spike recovery fails quality control limits (EPA current CLP statement of work)	Correlation coefficient ≥0.995	Qualify and accept data as reported
Detection Limits	Not applicable	(see Table 5)	Laboratory must initiate corrective actions and contact the QA/QC Coordinator and/or the Project Manager immediately
Field Quality Assurance/Quality Control			
Field Replicates	At Project Manager's discretion	±35 RPD (2 times CRDL for sample duplicate results >5 times CRDL)	Examine laboratory replicate results to rule out analytical imprecision; examine and modify sample homogenization procedures in the field
Cross-Contamination Blanks	At Project Manager's discretion	Analyte concentration ≥CRDL	Examine method blank results to rule out laboratory contamination; modify sample collection and equipment decontamination procedures

Table 10 (Continued)
Quality Control Procedures for Metal Analyses

Quality Control Procedure	Frequency	Control Limit	Corrective Action
Blind Certified Reference Material	Overall frequency of 5 percent of field samples	80–120 percent recovery	Project Manager decision: discuss results with laboratory; qualify sample results

Notes:
CLP - Contract Laboratory Program (EPA)
CRDL - contract-required detection limit
EPA - U.S. Environmental Protection Agency
GFAA - graphite furnace atomic absorption
QA/QC - quality assurance/quality control
RPD - relative percent difference

Instrument and method QA/QC procedures monitor the performance of the instrument and sample preparation procedures and are the responsibility of the analytical laboratory. When an instrument or method control limit is exceeded, the laboratory is responsible for correcting the problem and reanalyzing the samples. Instrument and method QA/QC results reported in the final data package should always meet control limits (with a very small number of exceptions that apply to difficult analytes as specified by EPA for the CLP). If instrument and method QA/QC procedures meet control limits, laboratory procedures are deemed to be adequate. Matrix and field QA/QC procedures monitor matrix effects and field procedures and variability. Although poor analytical procedures may also result in poor spike recovery or duplicate results, the laboratory is not held responsible for meeting control limits for these QA/QC samples. Except in the possible case of unreasonably large exceedances, any reanalyses will be performed at the request and expense of the project manager.

Table 11
Quality Control Procedures for Conventional Analyses

Analyte	Suggested Control Limit						
	Initial Calibration	Continuing Calibration	Calibration Blanks	Laboratory Control Samples	Matrix Spikes	Laboratory Triplicates	Method Blank
Ammonia	Correlation coefficient ≥0.995	90–110 percent recovery	Analyte concentration ≥CRDL	80–120 percent recovery	75–125 percent recovery	35 percent RSD	Analyte concentration ≤ CRDL
Grain size	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	35 percent RSD	Analyte concentration ≤CRDL
Total organic carbon	Correlation coefficient ≥0.995	90–110 percent recovery	Analyte concentration ≥CRDL	80–120 percent recovery	75–125 percent recovery	35 percent RSD	Analyte concentration ≤CRDL
Total sulfides	Correlation coefficient ≥0.990	85–115 percent recovery	Not applicable	65–135 percent recovery	65–135 percent recovery	35 percent RSD	Analyte concentration ≤CRDL
Total solids	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	35 percent RSD	Analyte concentration ≤CRDL

Notes:
CRDL - contract-required detection limit
EPA - U.S. Environmental Protection Agency
PSEP - Puget Sound Estuary Program
RSD - relative standard deviation

EPA and PSEP control limits are not available for conventional analytes. The control limits provided above are suggested limits only. They are based on EPA control limits for metals analyses and an attempt has been made to take into consideration the expected analytical accuracy using PSEP methodology. Corrective action to be taken when control limits are exceeded is left to the Project Manager's discretion. The corrective action indicated for metals in Table 10 may be applied to conventional analytes.

Table 12
Marine and Estuarine Sediment Toxicity Test Conditions

Toxicity Test Species	Frequency of Water Quality Monitoring: Temperature, Salinity, Dissolved Oxygen, pH	Frequency of Water Quality Monitoring: Sulfides, Ammonia	Control Limits: Temp (°C)	Control Limits: Salinity (ppt)	Control Limits: Dissolved Oxygen (% saturation)	Control Samples: Negative Control	Control Samples: Positive Control	Control Samples: Reference Sediment	Performance Standards[a]
Acute Effects Tests									
Amphipod *Rhepoxynius abronius*	Daily	Beginning/end (optional)	15±1	28±1	NA[b]	Clean sediment	Reference toxicant in seawater	Yes	Mean mortality in control sediment <10 percent and mean mortality in reference sediment <25 percent.
Ampelisca abdita	Daily	Beginning/end (optional)	20±1	28±1	NA[b]	Clean sediment	Reference toxicant in seawater	Yes	Mean mortality in control sediment <10 percent and mean mortality in reference sediment <25 percent.
Eohaustorius estuarius	Daily	Beginning/end (optional)	15±1	Ambient (same as interstitial)	NA[b]	Clean sediment	Reference toxicant in seawater	Yes	Mean mortality in control sediment <10 percent and mean mortality in reference sediment <25 percent.
Larval Oyster *(Crassostrea gigas)*	Daily	Beginning/end	20±1	28±1	>60[c]	Clean seawater	Reference toxicant in seawater	Yes	Mean combined mortality and abnormality in control seawater <70 percent.
Mussel *(Mytilus sp.)*[d]	Daily	Beginning/end	16±1	28±1	>60[c]	Clean seawater	Reference toxicant in seawater	Yes	Mean combined mortality and abnormality in control seawater <70 percent.

Table 12 (Continued)
Marine and Estuarine Sediment Toxicity Test Conditions

Toxicity Test Species	Frequency of Water Quality Monitoring		Control Limits			Control Samples			Performance Standards[a]
	Temperature, Salinity, Dissolved Oxygen, pH	Sulfides, Ammonia	Temp (°C)	Salinity (ppt)	Dissolved Oxygen (% saturation)	Negative Control	Positive Control	Reference Sediment	
Larval (Cont.) Sand dollar *(Dendraster excentricus)*	Daily	Beginning/end	15±1	28±1	>60[c]	Clean seawater	Reference toxicant in seawater	Yes	Mean combined mortality and abnormality in control seawater <70 percent.
Sea urchin *(Strongylocentrotus purpuratus or S. droebachiensis)*	Daily	Beginning/end	15±1	28±1	>60[c]	Clean seawater	Reference toxicant in seawater	Yes	Mean combined mortality and abnormality in control seawater <70 percent.
Chronic Effects Test									
Juvenile polychaete *Neanthes sp.*	Every third day	Beginning/end (optional)	20±1	28±2	NA[b]	Clean sediment	Reference toxicant in seawater	Yes	Mean mortality in control sediment <10 percent and mean individual growth ≥0.38 mg/individual/day[c]. Mean individual growth rate in reference sediment >80 percent of mean individual growth rate in control sediment.

[a]Performance standards in WAC 173-204-315(2).
[b]Continuous aeration is required by the protocol, so the dissolved oxygen concentration should not be cause for concern.

Table 12 (Continued)
Marine and Estuarine Sediment Toxicity Test Conditions

[c]Aeration should be initiated if the dissolved oxygen concentration declines below 60 percent of saturation
[d]PSEP (1995) and the SMS refer only to the use of *Mytilus edulis* in this test. However, it may be more accurate to refer to the test organisms used as members of the *Mytilus edulis* sibling species complex. Recent taxonomic studies of West Coast mussels (McDonald and Koehn 1988; McDonald et al. 1991; Geller et al. 1993) indicate that the mussels in Washington state are either *M. trossulus* (a more northerly species) or *M. galloprovincialis* (a more southerly species). The mussel species being used by most biological laboratories in the Northwest *is M. galloprovincialis*. *M. edulis* does not occur locally and is therefore unlikely to be used in toxicity tests.
This does not constitute a change in test organisms, but an acknowledgment that the organisms may have been previously misidentified.
[e]Changed from 0.72 mg/individual/day by 1995 Sediment Management Annual Review.